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CAR. I. TABORIS.

mous ; and it has come to be confessed by English politicians that on a matter of local importance deference should be paid to local wishes. The demand for Home Rule has operated to bring about this conclusion, and it is possible that minor results may continue to be achieved under cover of the larger platform. In this way the wisdom may be proved of asking for what nobody expects to get.

Whatever may be the motives and the hopes of the several members of the Home Rule Party, there can be no doubt as to the conduct that should be pursued by English and Scotch members in reference to their demands. The sting of the agitation for a separate Parliament should be taken away by a practical demonstration that the United Parliament approaches Irish questions with a candour no assembly could exceed, and in a spirit of impartial wisdom presumably greater than could be expected from a more contracted gathering. Irishmen should not be able to point to work neglected, nor to questions voted upon under the influence of prejudice, whether of English or of Scotch origin. We do not ask that legislation for Ireland should be absolutely controlled by Irish ideas, but we do ask that it should not be absolutely governed by English or by Scotch ideas. If the deliberations and decisions of Parliament were guided by this principle, and an honest attempt was made to relieve the inhabitants of Ireland from the grievance of having to come to Westminster for the benefits of the private Bill legislation they may require, the strength of the demand for Home Rule would be at once broken. Some ten years ago Mr. Dodson submitted to the House of Commons a plan

VORTEX MOTION.—The Friday evening discourse at the Royal Institution last week was given by Professor Osborne Reynolds, of Owens College, Manchester, his subject being "Vortex Motion." Professor Reynolds commenced by referring to the long series of distinguished lecturers who had stood in the place he occupied and delighted au[illegible] accounts of the triumphs of mind over [illegible] might rather be

William L. Carpenter Esq
from the Author

THE BEGINNING.

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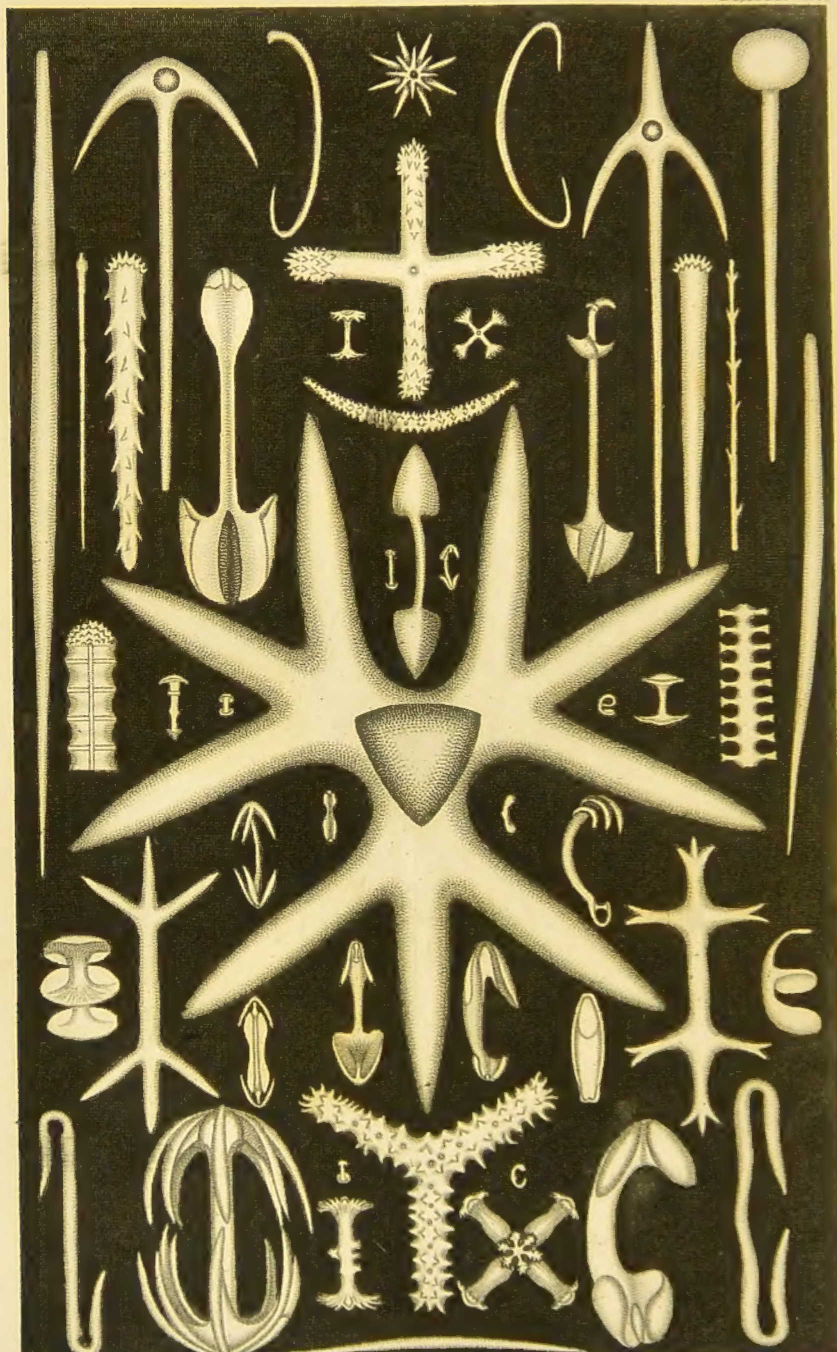
FRONTISPIECE.

PLATE M.



DRAWN BY M. PONTON. H. ADLARD SC.

SPONGE SPICULES.

THE BEGINNING:

ITS WHEN AND ITS HOW.

BY

MUNGO PONTON, F.R.S.E.

I have seen the travail which God hath given to the sons of men to be exercised in it. He hath made every thing beautiful in his time; also he hath set the world in their heart, so that no man can find out the work that God maketh from the beginning to the end.' · Ec. III. 10, 11.

LONDON:
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1871.

PREFACE.

'THE BEGINNING' is a topic which has occupied many a pen, from the days of old to the present time. Nevertheless, the continuous progress of modern scientific discovery renders it needful, from time to time, to amend our views and widen our field of research. The science of Geology is that by which the attention of inquirers has been hitherto chiefly engrossed. The phenomena which it has brought to light appeared at first sight so completely to undermine the preconceptions imbibed from ancient records and traditions, that much controversy was awakened. But the character of those phenomena and their true bearings are now so well understood, that it is no longer needful to dwell on them in detail.

Touching, therefore, but lightly on the facts of Geology, the following inquiry takes a wider range. The probable antiquity of matter, its earliest condition, the constitution of the luminiferous ether, and the probable manner in which matter may have become distributed into definite masses, constituting suns and planets, are first considered. Recent investigations have enlarged our knowledge of the solar energies, and their relation to the phenomena of life. To this subject accordingly has been given careful attention. The phenomena of organization, and in particular those connected with reproduction, are examined some-

what in detail. The way being thus opened for a review of the theories which have been propounded, in reference to the first origin of organic genera and species, this interesting topic is discussed at large.

To the main body of the work has been added a second part on the subject of the possibility of reconciling the Hebrew records, relating to 'The Beginning,' with modern scientific discoveries. The Notes contain some details, which could not have been so well introduced into the text.

The illustrations have reference to that portion of the work which relates to organic forms, and the objects represented are nearly all microscopical. While a few of the drawings of individual objects were copied from other works, the larger proportion were taken from actual specimens, some of them of great rarity. My best thanks are due to those kind friends by whom many of the objects delineated have been so liberally supplied. To my esteemed friend the Reverend Walter J. Whiting, I am specially indebted for the beautiful photographs, from which plates N and P were taken.

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THE BEGINNING:

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PART I.

CHAPTER I.

THE ANTIQUITY OF MATTER.

In treating of the Beginning, the first question which naturally presents itself for consideration is that of the antiquity of matter. By the term 'matter' is to be understood that substance of which all objects perceptible by the senses are composed. It thus includes our own terraqueous globe, all the heavenly bodies, and the luminiferous ether. It may be rigidly defined as 'an assemblage of substantial ultimates, each having for its essential properties definite size, definite form, and impenetrability.' These ultimates may also have relative properties, in virtue of which they may either attract or repel each other; but it is conceivable that they might exist without such relative properties. From these last, where they do exist, result all the forces exerted by matter.

The intellectual faculties of man being limited, the distinct conception of either infinite duration or infinite extent is utterly beyond his ken. The human mind

indeed can form to itself a hazy notion of an eternal future, by conceiving the planetary and stellar motions to be continued for ever; and it can also form a faint idea of its own interminable existence. But when it attempts to scan the eternal past it becomes bewildered and lost. So also with respect to infinite extension. If the mind tries to form to itself an idea of anything infinitely extended, it becomes exhausted in the effort. This inability, however, does not prevent the mind from entertaining the conception that there may be being without limits either in duration or extent. On the contrary, human reason understands that such must exist.

The ubiquity of the Divine presence the rational mind apprehends as a necessity; yet of that omnipresence it can form no distinct conception. In like manner, seeing that the supposition of an elastic ether is necessary to explain the phenomena of light, the mind understands that such an ether must be infinite in extent. The reason is, that, from its being perfectly elastic, were there any empty space into which it could expand, it would be in a state of continual expansion; so becoming rarer and rarer—a change which would be rendered evident by an alteration in the speed with which light travels. But as no such alteration can be detected, the conclusion is inevitable, that the elasticity of the ether is constant—consequently that there can be no space where the ether is not. Its extent must be infinite. But this conclusion does not help the mind to form a conception of this infinite extension. The universal diffusion of the ether is equally beyond our distinct comprehension with the universal presence of the Divine Being.

When the mind has thus been brought to the conclusion that matter is infinite in its extension, it begins to conceive the possibility of matter's being infinite also

in its past duration. Since there is no space where matter is not, so there may never have been any epoch when it was not. Indeed the mind feels a great difficulty in forming to itself the opposite conception. It apprehends that there must always have existed a Being possessed of power, will, and invention ; but it is difficult for it to think of this Being as having ever existed alone, without a *somewhat* upon which his power might be exerted. The idea of activity forms so essential a part of our conception of a living, willing, and understanding mind, that it is nearly impossible for the human intellect to form to itself a notion of such a mind's having remained during an indefinite period in the past eternity, in a state of absolute repose, by reason of the total absence of aught whereon to exert will or power. It would likewise be unphilosophical to conceive of more than one eternal mind—consequently to imagine the divine mind to have always had another mind, or other minds, whereon to exert activity. The human understanding is thus led to regard it as not impossible that there may always have been not only a mind possessing power, but also some passive essence upon which that powerful mind might act ; and that if there was such a passive essence, it must have been not spiritual but material.

Contemplating the present order of the universe, human reason understands that the divine mind acts upon and through matter, and that this action is the final cause of all physical effects. Thus the material universe stands to the divine mind in a relation somewhat resembling that in which the brain of man stands to the human mind, as the medium upon and through which it acts. Matter is the organ of the divine intellect. But whether or not the existence of matter be essential to the activity of the divine mind it is impossible to say; because, being utterly ignorant of the ultimate nature of matter viewed

as the substance of all bodies, or of spirit viewed as the substance of all minds, we cannot discern whether, in their existence, these two essences be mutually necessary to each other or not. It is quite possible that both may have existed always; but if one of them existed before the other, the pre-existence must obviously rest with spirit; for matter, having neither will nor invention, could not create mind, which has both; neither could matter form itself into those arrangements which exhibit evidences of design. But mind pre-existing could give to matter all those forms and arrangements which display inventive power.

On the other hand, we strive in vain to form any conception of spirit, or mind, existing apart from, or independently of matter. Such a conception quite eludes our grasp. Nevertheless, it is obviously necessary to suppose mind to have existed always, as the ultimate cause of all design. But this eternal mind must have created all subordinate minds; and it is impossible to imagine that, in the performance of that act, the Eternal Spirit was under the necessity of employing already existing spirit to constitute such subordinate minds. For the Eternal Spirit being all-pervading, such pre-existing spirit could be only portions of itself; so that all subordinate minds would be not new creations, but mere multiplications by self-division of the all-pervading spirit. Every subordinate mind would thus be simply a portion of the universal mind; so that all the thoughts and actions, whether good or bad, of every subordinate mind, would be merely parts and portions of the thoughts and actions of the universal mind—a conclusion which is manifestly absurd. Hence, it is clearly needful to suppose all subordinate minds to have been created by the simple volition of the eternal mind. Now, if the mere will of the eternal mind be thus capable of absolutely creating

spirit, it is evidently not impossible that it should be likewise capable of absolutely creating matter; for the latter act is not so high a stretch of power as the former.

While it is thus impossible to deny to the Deity the power to have absolutely created matter, supposing it to have been originally non-existent, the possession of such a power does not prove that it was actually exercised. The difficulty thus recurs of forming the conception of an active intelligent mind's having remained for an indefinite period of the past eternity absolutely at rest, for the mere want of a somewhat upon which activity might be exerted. On the other hand, if, to remove this difficulty, it be supposed that matter existed always, and was always either the medium or the subject of the Divine action, it is needful to imagine that at some remote period in the past, the ultimates of matter existed without any other properties, except those of mere being, impenetrability, form, and size: for the other properties of both the ponderable and imponderable ultimates are such as to exhibit the most manifest traces of design, of intelligent forethought and intention. The gravity of the ponderable ultimates, their powers of cohesion and chemical affinity, all present striking examples of law and order. Nor less remarkable are the laws which regulate the properties and relations of the luminiferous ether—also displaying the intentions of a highly mathematical and calculating mind. Hence the axioms, that every design must have had a designer, and every intention an intending will, render inevitable the conclusion that these properties must have been conferred on matter by a designing mind, characterized by a love of order, law, and symmetry. Wherefore, if matter existed at all from everlasting, it must have been originally destitute of those properties, and must have consisted of an assemblage of ultimates, having only existence, form, magnitude, and impenetra-

bility, but no other properties whatever—no mutual relations, each absolutely indifferent to every other. This is a conception not quite so difficult to form as that of an active being's having remained for an indefinite period inert for want of a somewhat whereon to act.

In Calderwood's 'Philosophy of the Infinite' (second edition, p. 41) occurs the following passage—'To believe that matter is eternal is to contradict the fundamental convictions of our minds. That the limited is independent—that the changeable is self-existent—that the perishable is eternal—these are the transparent contradictions involved in the assertion of the eternity of matter.' Now all the three averments here affirmed of matter as being acknowledged truths, are mere unwarranted assumptions. There is no proof that matter is limited; on the contrary, there are the strongest grounds for believing it to be unlimited. We have not the slightest evidence that matter is changeable. There is no example of any one kind of material ultimate's being converted into another, or undergoing any permanent change in its essential nature or properties. It may enter into new and varied relations, but in its essential constitution it remains unchanged. Neither have we any proof that matter is perishable; no single ultimate of it has ever been destroyed within the range of human cognizance; nor have we the least reason to suppose that any particle of it is essentially destructible. Thus all the three grounds on which the eternity of matter is, in the above-quoted passage, pronounced to be contradictory of our fundamental convictions, are utterly fallacious.

Still the difficulties besetting such a conception as that of the past eternity of matter are great; so that the mind is here placed, as it were, between the horns of a dilemma. The two probabilities—the one, that matter may have existed always; the other, that it may have been

absolutely created by the mere volition of the one eternal mind—are nearly equally balanced; and human reason is incapable of determining their respective values. The philosophic mind will, therefore, here hold itself in suspense; adopting the language of the Hebrew bard, 'Such knowledge is too wonderful for me; it is high, I cannot attain unto it.'

With the physical forces, again, it is quite otherwise. There is here left no room for hesitation or doubt. Physical force, in all its varieties, is governed by laws the most subtle and wonderful—exhibiting incontrovertible evidences of will, intention, skill, with a love of order, symmetry, and mathematical arrangement. These are qualities of mind, not of matter, consequently the physical forces must have had their origin in the will of a designing mind. So certain is this conclusion, that any mind which does not perceive its truth may be pronounced insane.

CHAPTER II.

THE FIRST CONDITION OF MATTER—THE ORIGIN OF LIGHT AND HEAT—THE FIRST SEPARATION OF MATTER INTO DISTINCT MASSES.

In forming a conception of what may possibly have been the first condition of matter, it is needful to bear in mind the ever subsisting uncertainty as to its antiquity, and to form such an idea of it as shall be consistent either with the view of its having possibly existed always, or with the view that it may have been brought into being by a mere act of will exerted by the infinite and eternal mind, at some definite epoch in the past.

The only conception which appears admissible under the former alternative is, that matter was at first a mere assemblage of substantial ultimates, each having definite size, definite form and impenetrability, but having no relative properties whatever, each ultimate being absolutely indifferent to every other ultimate in the universe. This conception is equally admissible under the second branch of the alternative, although not the only one that might be so admitted. There is at least no inherent improbability in the supposition, that if matter was at first brought into being by a mere act of divine volition, it may, when first thus created, have been in the state above indicated. Such a conception of the earliest condition of matter may therefore be regarded as a fair starting point for further inquiry.

This assumption involves the necessity of supposing these indifferent ultimates of matter to have had their relative properties subsequently conferred upon them by an act of divine volition, accompanied by an exercise of foresight, design, and inventive power. It has already been mentioned that the phenomena of light render it needful to assume the existence of an elastic ether, which must be infinite in its extension. If, then, the ultimates of matter were originally all alike, and absolutely indifferent to each other, they must have constituted one homogeneous infinitude. Or rather, seeing the phenomena of luminous vibrations in the ether render it indispensable to suppose its constituent ultimates to be capable of motion, and as every motion requires a certain amount of space in which it may be performed, it becomes needful to assume that the material ultimates were separated one from another by minute spaces; so that the substantial ultimates with the intervening spaces must be regarded as having at first constituted the original infinitude.

The subsisting relative properties of the ultimates of matter are two—repulsion and attraction. Each ultimate endowed with either of these properties, appears to be capable of influencing all other ultimates around it, to an indefinite distance from its own immediate centre of presence. The ultimates constituting the luminiferous ether are all endowed with the property of repulsion, and that in a very high degree. The ultimates constituting all heavy bodies are endowed with the property of attraction; but, as will be afterwards shown, this power of attraction is immensely inferior in degree to the power of repulsion possessed by the ultimates of the ether.

Now, when we consider this vast superiority of the latter force, and the important part which it performs in the economy of nature, bearing in mind also that the ultimates which possess it must be almost infinite in number,

while those endowed with the force of attraction must be far less numerous; it appears fair to conclude, that, if there was a succession in the conferring of these relative properties, the repulsive power given to the constituent ultimates of the ether was that which was most probably first bestowed, the other ultimates meanwhile retaining their original condition of mutual indifference. There is thus nothing unphilosophical in the idea, that the first species of physical force which existed in the universe was the mutual repulsion of the ultimates of the luminiferous ether. This granted, it may be further fairly inferred that there is nothing improbable in the supposition that the first species of motion which existed in the universe consisted of the vibratory movements of the ultimates of the ether, regulated by their mutual repulsion and the laws by which it is governed. These movements constitute the phenomena which we call light, and which may accordingly have been the first of all the phenomena displayed in the material world.

This idea may at first sight appear to be inconsistent with what is observed respecting light as it now subsists; for in every case falling under our observation, light appears to proceed from some centre in which the vibratory force has its origin; whereas, in the case supposed, there was nothing corresponding to such a centre of force.

In treating of this earliest condition of the material universe, however, it must be borne in mind that we can look to no other ultimate source of motion than the vital energy of the Divine Being. It is acknowledged by all right-thinking philosophers, that the first origin of motion, which of necessity involves the idea of force or power, cannot with any show of reason be referred to any other cause whatever; in so much that, if this cause be ignored, the first origin of motion becomes utterly inex-

plicable. For, as no motion exists that is not governed by determinate mathematical laws, it is impossible to assign to any motion a first origin other than an intelligent designing mind. This much being granted, it will appear nowise inconsistent with sound philosophy to suppose the divine energy to have been, in the first instance, applied to give vibratory motion to the ultimates of the ether, immediately after they were endowed with the property of mutual repulsion, and this without the necessity of imagining such vibratory motion to have proceeded from any definite centre or centres. For a motion of this nature, pervading a large portion of the infinite ether, may have been necessary to the further development of the designs of the Deity, and may in particular have been required for producing a certain amount of corresponding vibratory motion in those ultimates which were to be endowed with the property of attraction. In them such a vibratory motion would constitute what we call heat or temperature.

It is unnecessary, however, to limit ourselves to the supposition, that the first motion which existed in the universe was primarily imparted to the ultimates of the luminiferous ether themselves. For supposing the other ultimates, which are now accumulated into gravitating masses, to have been at first widely diffused throughout the ether, the vibratory motion may with equal probability be supposed to have been primarily generated in them, constituting in them a certain amount of temperature. Thus each of these ultimates would become in itself a centre of motive energy, and would communicate a portion of its motion to the ethereal ultimates surrounding it. But this power of communicating their motion to the ether could not exist unless there had been previously established a repulsive force between the two sets of ultimates. The one set while remaining

indifferent to each other, becoming repulsive towards the ethereal ultimates; while these last were furthermore rendered repulsive towards each other. This view would remove any difficulty arising out of the absence of a centre of force, which appears to be involved in the idea that the motion was at first directly conferred on the ultimates of the ether.

Thus the discoveries of modern science, which prove that light consists of the vibrations of the ultimates of an infinite elastic ether, while heat consists of similar vibrations in the particles of heavy bodies, lead fairly to the inference that of all the physical phenomena of nature, the first that had origin may not improbably have been light and heat.

If these views be correct, it will follow that the next step was, in all likelihood, the conferring on the reserved portion of the substantial ultimates, which had not been endowed with repulsion, that property of mutual attraction which constitutes gravity, and the aggregation of those ultimates into separate masses of definite size, form, and weight. Such an operation could not be accomplished otherwise than by a direct action of the divine energy. When we consider the peculiar nature of the laws governing the force of gravity—its being directly proportional to the mass, and inversely proportional to the square of the distance—it must become evident to every one capable of reflection, that such a force, regulated by such laws, could have been derived from no other source than the will of an infinitely intelligent and calculating mind. If, then, the substantial ultimates, which now possess the force of gravity, at one time existed throughout a portion of the ether in a state of absolute mutual indifference, it is indispensable to suppose the direct action of this intelligent mind to have been brought into exercise in conferring that property. There is, indeed, the alternative

supposition, that these particular ultimates may have been primarily created by the Deity with the force of gravity inherent in them. But this alternative is not consistent with the idea that these ultimates may have existed always—a point which must ever remain uncertain; while it, equally with the other alternative, involves the idea of the direct interference of an intelligent mind. On the other hand, it does not appear admissible to imagine the heavy ultimates of matter to have always existed with the inherent property of gravitating attraction; because such a hypothesis would involve the idea of design existing without a designer, law without a law-giver—an idea from which sound reason recoils. On the same ground, it appears impossible to hold that the material masses—the terraqueous globe and the heavenly bodies—whose ultimates are held together by attraction, can have always existed in that condition.

It may be further shown to be highly improbable, that those material masses could have been originally created in their present state of aggregation. For this supposition would be inconsistent not only with the idea that the material ultimates themselves may possibly have existed always, but also with certain physical phenomena to be presently noticed. The most reasonable view, then, is, that the substantial ultimates, which now possess the attraction of gravitation, primarily existed in a state of absolute mutual indifference, and had that property conferred upon them, at a remote epoch in the past, by a direct act of divine volition.

This conclusion, again, involves the necessity of admitting another direct interposition of the divine will, in order to effect the separation of the gravitating ultimates into distinct masses, each proportioned in size and weight to the position it was to occupy, and the end it was to serve. For it is obvious that the force of gravity, acting alone,

would have accumulated the diffused ultimates into one single large mass. Nothing save a guiding intelligent power could have caused them to assemble into *separate* masses, disposed and associated as are the heavenly orbs. We have, moreover, in the particular case of the planetary system, a curious proof of the superintendence of an intelligent mind. Had the separate planetary masses and their satellites been formed by vortices, arising from any mere physical cause, and operating under the influence of one general physical law, the vortices would all have whirled in one direction. At least, no reason could be assigned why some of them whirl from left to right, and others from right to left. But in the fact that the satellites of Uranus and Neptune revolve in a direction contrary to that in which the satellites of Jupiter, Saturn, and the Earth revolve, there is evidence that the primary vortices, in which these several systems had their origin, must have had a contrary motion imparted to them by intelligent choice.

While recognising, to its fullest extent, the necessity for the direct interference of a superintending intelligent mind at this stage of the creative process, it is needful to beware of pushing that idea beyond its proper limits. Although it be quite conceivable that the Deity might, by mere volition, cause the ultimates endowed with weight to assemble into various individual masses, in predetermined portions and positions, it seems, nevertheless, more probable, and more in accordance with what we observe of the divine procedure, to suppose that, to produce those effects, he adopted adequate means. Were we to imagine Him to have endowed all the ponderable ultimates with the property of weight at one and the same instant of time, we should then have no alternative but to suppose Him to have constrained them, by a mere act of volition, to assemble in definite proportions around certain centres in determinate localities. But such a notion appears neither

necessary nor probable. It seems more consonant with our ideas of an orderly procedure to suppose the Divine Being to have first, and while the ultimates were yet in a state of mutual indifference, decided upon the centres around which he wished them to assemble, and the proportions in which they were to accumulate ; and secondly to have proceeded by developing the force of gravity in those centres in the first instance, conferring the property of weight upon the ultimates, not simultaneously, but successively, and that with various degrees of rapidity. In those centres around which He intended a large number of ultimates to assemble, the force would probably be imparted to them early and in rapid succession. In those around which the number of congregated ultimates was to be small, the force would probably be imparted later, and the succession would be comparatively slow. Thus the number gathered round any centre would be proportional to the rapidity with which the force of gravity was developed in the molecules destined to form the individual mass.

In this manner the whole suns, planets, and comets in the universe may have been formed into distinct masses by the operation of one single force, acting according to a determinate law. But by this procedure these bodies could be brought no further than into the first stage of their existence as individual orbs. They would all be gaseous, and perfectly spherical ; so that their separation from the ether would be still incomplete. It was therefore needful that new relative properties should be conferred on the ultimates, with a view to a further condensation of the masses, and the formation of substances of different kinds.

Of these additional relative properties, the most important is that species of electrical polarity which characterizes different chemical substances, and is manifested

in their chemical affinities. The second in importance of these relative qualities is the power of cohesive attraction, with its distinctive polarities, as manifested in the varieties of crystalline forms, in virtue of which power bodies assume either the liquid or solid condition.[1] By the combined action of these two relative properties—chemical affinity and cohesion—conferred upon the ultimates after they had assembled round their appointed centres, the vaporous masses would pass, not by slow degrees, but rapidly, into the more condensed liquid or solid states. Those ultimates endowed with similar electrical relations would assemble into distinct aggregations, forming the various species of metals and other chemical elements; while each entire mass would suffer an enormous decrease in volume, thus becoming separated to a still greater extent from the illimitable expanse of the luminiferous ether.

Nor is this idea, that the particles of matter composing the various globes of the universe were endowed with the force of gravity, chemical affinity, and cohesive attraction, not simultaneously but in succession, a mere unauthorised fancy destitute of all proof; because in like manner as in the animal and vegetable kingdoms, we find certain types and forms which are, as it were, arrested at a particular stage of their development, while others proceed to a higher point, so we have something analogous in the heavenly orbs. For the comets appear to have

[1] A doubt has been recently started as to there being any fundamental difference between the forces of cohesion and simple gravitation, but on insufficient grounds. So long as the three simple gases, oxygen, hydrogen, and nitrogen, when free from combination, withstand all attempts to bring them into the liquid or solid condition, it must be held that the ultimates of those gases, while possessing weight and chemical affinity, are, in their free state, destitute of that peculiar species of attraction which would enable them to become liquid, and of that sort of polarity which would enable them to pass into the solid form.

been endowed with gravitation and chemical affinity only. They still continue in the state of vaporous masses—at least they have never been observed in any other condition; nor have we any good reason to suppose them to pass into either the liquid or solid form; and in the absence of all proof, it should not be assumed that they ever do. Recent researches by Professor Tyndall render it probable, that the gaseous matter of comets extends continuously all round the nucleus, to the extreme limits of the tail, which is produced by what may be called a heat-shadow, projected on the gaseous spheroid, the non-luminous part of which is of too high a temperature to be capable of reflecting light. But that portion of the solar radiation which passes through the nucleus has so much of its heating power absorbed in the transit, that it can no longer maintain the same high temperature to the rearward; and the portion of the gaseous medium behind the nucleus is thus rendered sufficiently cool to reflect the solar light, and produce the luminous train.

The circumstance that comets thus maintain the gaseous state may accordingly be regarded as, to a certain extent, an evidence tending to substantiate the view of the order of the creative processes above set forth. Moreover there are grounds for believing that the comets may not be the only bodies in the universe similarly constituted. Recent observations with the spectroscope have raised a probability that some of the nebulæ are also in this same vaporous condition—indicating an absence of cohesive attraction in their component ultimates.

One thing is obvious, that, granting these relative properties to have been conferred—not simultaneously, but successively, the order above assigned must be correct. Weight must have been developed first; because bodies combine chemically in definite proportions by weight;

and both gravity and chemical affinity must have preceded cohesion, otherwise like particles could not have cohered to like, nor could any compound body have been formed, unless chemical affinity had been conferred before cohesive attraction. Now the mere fact of the quality of mutual attraction's being possessed by only a definite portion of the material ultimates in the universe, while the larger remainder exhibit mutual repulsion, tends to prove that neither of these two properties is inherent in matter; consequently it is legitimate to suppose matter to have at one time existed without either.

Again, if it be once admitted that the material particles may have existed without either the mutually attractive force of gravity, or the mutually repulsive force that pervades the ether, then it follows that they may in like manner have at one time been destitute of either chemical affinity or cohesive attraction, seeing that weight enters as an element into the development of both of those powers.

While it thus appears to be indispensable, with a view to any rational explanation of the formation of the masses of the heavenly bodies, to suppose their component particles to have been originally quite indifferent to each other, and to have been endowed successively with the properties of weight, chemical affinity and cohesion, similar views may be extended to the ultimates composing the ether; for the phenomena of electricity, magnetism &c., seem to render it needful to assume the existence of at least two kinds of ethereal particles, which, while both mutually repellent, have nevertheless distinct relations to each other, and to the particles possessing weight. It is accordingly fair to conclude, that, while the ponderable particles were endowed with the properties of chemical affinity and cohesive attraction, the repulsive ultimates composing the ether were either previously or at the same

time endowed with those other relative properties, which are traceable in electric, magnetic and other similar phenomena.

The probability that the spherical masses which now form suns and stars, planets and comets, were all originally elaborated out of what was once a continuously diffused medium, is enhanced by the fact of there being, in our own planetary system, certain very small bodies which seem to have been left out, when the sun and planets were being formed into separate spheroids. These minute bodies make their appearance occasionally as meteors or asteroids; and it is now well ascertained that one very large assemblage of them pay us a visit every thirty-three years, in the month of November; the last great display having taken place early in the morning of November 14, 1866. The existence of these bodies, which may be regarded as planetary refuse, is very adverse to the notion that the suns and planets may have been primarily created as separate spheres.

CHAPTER III.

THE PRIMARY TEMPERATURE OF THE MATERIAL MASSES.

If the foregoing views in regard to the mode of formation of the material masses be correct, it will follow that the whole globes of the universe, including the earth, were most probably at first heated to a very high temperature, and were at one time in a molten condition, from which they cooled down by slow degrees; so that portions of them, in virtue of their newly acquired property of cohesion, with its distinctive polarities, ultimately crystallized into solid forms. That our own globe was at one time in a state of igneous liquidity, the aspect of its lower strata leaves little room to doubt. The fact is also confirmed by the oblate spheroidal figure of the earth; and as the heavenly bodies, so far as they lie within the sphere of our observation, possess the same species of form, the presumption is strong, that they also were originally in the same molten state.

It has been mathematically proved, however, that the figure of the earth is not such as would be assumed by a fluid globe of uniform density, or whose density increased as the pressure; neither is it such as could be assumed by a solid or rigid body, but its form is such as would be acquired by a body passing from a state of fluidity or viscidity, to a solid or partially solid condition. The proportion of its equatorial to its polar diameter is nearly as 299 to 298, a ratio irreconcilable with any other than this last supposition. It has been further proved that its

figure is consistent with the supposition of the earth's having a solid crust, whose interior may be either wholly or partially fluid, provided the crust be of some considerable thickness; not less than one fifth, and more probably one fourth, of the radius of the globe. The density of the globe does not follow the simple law of increasing as the pressure. Its mean density is generally reckoned at between five and six times that of water; while that of its outer strata is about half of the former proportion.

We may hence draw the conclusion, not that our globe never was a fluid of uniform density, or whose density increased according to the simple law of the pressure, but that it did not acquire its present figure, while gradually cooling down from the state of a gaseous fluid at a high temperature. The globe was most probably indeed, as already shown, at one time in such a gaseous condition; but if so, it must have condensed somewhat suddenly into a state of liquidity or viscidity. The assumption of the latter condition was accordingly more probably the cause of its high temperature, than the consequence of its slow cooling. If gases be suddenly compressed or liquefied by other means than the abstraction of their heat, they acquire a sudden and great elevation of temperature in assuming the more compact form. The heat thus rendered sensible is exactly equivalent to what it would have been requisite to apply, in order to have expanded the body from the more compact into the gaseous condition.

The cause of this rise of temperature is obvious. By the sudden compression of the molecules, the amplitude of their vibratory motion is at once greatly reduced. This smaller extent of motion is consequently performed in a much shorter period of time, and as the temperature depends more on the rapidity than on the amplitude of the motion, it appears to increase. The actual quantity of motion is not lessened; but that portion of the motive

force, which was formerly expended in amplitude and extended over a larger space, is now expended in rapidity and confined within narrow limits; halving the amplitude, quadrupling the rapidity.

The present figure of the earth then lends no support to the supposition, that its form was acquired during its gradual cooling from a gaseous to a liquid, and thence to a solid state; for in that case it would have assumed the shape due to a fluid having a density increasing as the pressure; a form from which its figure differs very considerably. There is accordingly no proof whatever of the earth's having thus slowly cooled from a gaseous condition. But the actual figure, while thus hostile to this hypothesis, is highly favourable to the view, that the universal ether was at one time agitated throughout a large portion of its extent by luminous tremors, and that all the substantial ultimates, now composing the earth and heavenly bodies, were at first intimately blended with the ether, so that there must have been a perfect uniformity of temperature pervading the whole mixed materials. Nor is it needful to suppose this temperature to have been high; for the capability of bodies to acquire temperature from the vibrations of the ether diminishes as their density decreases; so that bodies of great rarity acquire but little heat from the ethereal tremors. Such an uniformity of temperature, however, would absolutely exclude the idea, that the ponderable masses of the universe acquired their consistency by gradual cooling; for no part of the medium could begin to cool where all was equally warm. Even granting that there may have been an exterior limit, beyond which the ethereal tremors did not extend; consequently that it was possible for the agitated portion to lose motion by imparting it to the still portion, the matter originally diffused through the ether would, if it had acquired consistency by slow cooling, have formed

only one large mass; so that the formation of separate masses would be still left without any explanation.

To account for this last effect, we must suppose that the elements were originally destitute of weight, and that the Great Artificer, designing to form the universal material into separate masses, not only conferred on the hitherto indifferent particles the property of mutual attraction, obeying the law of the inverse square of the distance, but also that He caused this force to become developed with various degrees of rapidity in certain centres, all previously arranged in His mind with wonderful skill and forethought. We must conceive that the diffused materials immediately began to assemble round those centres in vaporous masses, proportioned to the intensity of the force developed in each—that shortly thereafter, their particles having been endowed first with chemical affinity and next with cohesive attraction, the masses became rapidly condensed, and their temperature consequently rose to a very high pitch. To produce this last effect, the decrease of volume must have been sudden. It may hence be inferred that the forces of gravity, chemical affinity, and cohesion were developed before the centrifugal or tangential force, in order that, from their operating without any counteraction, the effects of the gravitating and cohesive forces might be equally sudden and powerful.

The probability that each of the planets was thus separated by weight and measure, under the guidance of a Supreme Mathematical Intelligence, has been enhanced by certain calculations, which have been recently submitted to the French Academy by M. Flammarion. These tend to prove that there is a peculiar relation between the specific gravity of a planet, and the period of its rotation on its axis. Taking the number of times which that period exceeds the time in which a satellite would

freely revolve round the planet at its equator, he finds it to be in the case of the earth 17 times, in the case of Jupiter 3·6 times, and in the case of Saturn 2·7 times, which numbers stand to each other in the same ratio as do the densities of those three planets. Should this relation be ultimately established, it will tend greatly to strengthen the argument in favour of the view, that the material masses, on being separated from each other, had their quantities of matter, their volumes, their periods of rotation and revolution, all assigned to them by a presiding Mind.

CHAPTER IV.

THE TERRAQUEOUS GLOBE.

The probable manner, in which the original materials of the universe were assembled into separate masses having been indicated, special attention may now be directed to that particular mass which constitutes the terraqueous globe.

It has been pointed out that the forces of gravity, chemical affinity and cohesion, by which the separation of the masses was effected, probably acted with immense rapidity, and so as to cause a great rise of temperature in the condensed materials. It has also been shown that this condensation probably occurred before the development of the centrifugal or tangential force.

To this idea the peculiar proportions of the earth's equatorial and polar diameters lend a strong support. These indicate that its figure was not assumed until the globe had acquired a considerable amount of consistency, nor until its materials had been arranged, as respects their relative density, very much in the manner in which they are now found. It may therefore be fairly inferred that the earth's rotation on its axis, and the tangential force accompanying that rotation, to which the earth's figure is due, did not begin till after its condensation from the gaseous condition. Moreover, from the circumstance that the increase of density towards the earth's centre does not follow the simple law of the pressure, it

may likewise be fairly inferred that the condensation was sudden.

With respect to the rise of temperature, again, it will be readily understood that the same amount of motive force which was at first universally distributed over the whole ultimates diffused throughout the ether, being now exerted on the same ultimates concentrated into spaces of incomparably smaller size — the resulting temperature would be as much higher than what previously prevailed, as the spaces into which the ultimates became compressed were smaller than those through which they had been formerly diffused. Thus the figure of the earth and the appearance of the strata both combine to prove that a very high temperature must have at first prevailed in the earth, and that the globe did not assume its present form by slowly cooling from a gaseous state, which it previously possessed in virtue of a still higher temperature; but that, while it was in the gaseous condition, its temperature was lower; and it rose in consequence of the condensation of the materials from the aëriform to the liquid state.

With respect to the manner of cooling of the mass thus agglomerated, it may be fairly assumed to have proceeded according to the subsisting laws; and if so, it must have occupied a very long space of time.

Judging from the analogy furnished by the manner of cooling observed in the case of volcanic lava, the external surface of the molten mass, being exposed to the free ethereal expanse, would, like a body placed in the vacuum of an air-pump, rapidly lose temperature, and a crystalline crust would speedily be formed over the entire surface of the globe. Some have imagined that, in cooling from the surface downward, the exterior particles, gaining specific gravity as they lost temperature, would descend toward the centre, so causing the whole mass to

become viscid before any crust was formed. Analogy and experience however are against this view. The fluid at the exterior would have a specific gravity not much exceeding two and a half times that of water, while the specific gravity of the interior parts would be considerably higher. Hence unless, on their cooling, the specific gravity of the outer particles were much increased, they would not sink into the lower strata of heavier fluid. Now the difference of specific gravity between melted and solid granite is small; wherefore if the cooling proceeded rapidly at first, as it would do under the circumstances supposed, the outer particles would not have time to sink before becoming solidified into a continuous crust. The first crystallization would accordingly take place suddenly over the whole surface, and the solidification would thereafter proceed in the same manner as the formation of ice on water, or as the crust on lava. As happens in this latter case, on the crust's increasing in thickness, the progress of the cooling would be slower; for the heat would have to pass outward by conduction through the already solidified portion, whose conducting power would be small compared with that of the fluid.

It has by some been supposed that, simultaneously with the crystallization proceeding from the surface downward, there may have been a solidification extending from the centre outwards. Such might arise from the mere influence of pressure; but only if that influence, tending to solidification, exceeded the influence of the high temperature tending toward liquefaction. Our ignorance of the proportion subsisting between those two opposing influences renders it impossible to pronounce with any certainty on this point. The experimental evidence, so far as it goes, rather militates against the idea of mere pressure's aiding solidification; for although water has been subjected to a pressure sufficient to force it through

the pores of an iron cylinder ten inches in thickness, it manifested no tendency to pass into ice. The solidification by pressure of semifluid substances, like wax and tallow, probably arises from the separation thus effected between a true solid and a true liquid, previously intimately blended, rather than from the solidification by pressure of a true liquid. The effect of high pressure in raising the melting point of wax by 30° F. is probably owing to the pressure's preventing the more solid constituents of the wax from being dissolved by the more fluid, the former being thus enabled longer to resist the melting power of the heat. Tin, barytes, &c., on subjection to pressure, show no elevation of their melting point. Experiments on the fusion of limestones show that, in certain cases, pressure aids a high temperature in producing liquefaction; but there are no experiments tending to prove its assisting a reduction of temperature in solidifying a true liquid like mercury or water. On the other hand, it has been ascertained that high pressure applied to ice, when near its melting point, aids its liquefaction; while there are strong grounds for suspecting that water, when brought into contact with mineral substances at a high temperature and under a great pressure, tends to liquefy them, and that similar effects are produced by gases reduced to liquidity by an enormous pressure. These effects are supposed to be exemplified in the case of volcanic lavas.

After a certain thickness of crust had been formed, it may be imagined that in virtue of chemical action proceeding in the interior of the globe, not by chance, but by the design of the Great Artificer, and even in consequence of the mere solidification of the liquid mass, there became extricated a vast quantity of gaseous matter comprising a large proportion of watery vapour. These aëriform materials would accumulate between the molten

mass and the solid crust, until their elastic force became so great as to burst the shell. The vapours would thereupon escape through the fissures, spreading themselves over the outer surface, while the solid crust would sink down till it again came into contact with the molten mass.

This is the only conceivable way of accounting for the disruption which the crust seems obviously to have undergone; for except by the extrication of vapour, the internal fluid could not have increased in volume, so as to rupture the solid shell. Its gradual cooling would tend rather to decrease than to enlarge the volume of the liquid. If again it shrunk so much as to leave a void between it and the crust, the latter, being a solid of equilibrium and having no weight pressing on it, would have remained unbroken, had not the intervening void become filled with vapours sufficiently elastic to rend it asunder.

The escape of those vapours would be attended by a great and sudden fall of temperature; so that the cooling would afterwards proceed with renewed rapidity. More of the melted materials would be congealed under the ruptured crust, which would thus become again cemented into a solid dome.

A considerable addition having thus been made to the thickness of the crust, another extrication of gas and vapour may be supposed to have taken place underneath it, followed by a second eruption; and this operation may have been repeated many times in succession, till the external crust had acquired sufficient thickness, and there had accumulated on its surface an adequate amount of gaseous matter to constitute the atmosphere and of watery vapour to form the ocean.

As the cooling proceeded, the watery vapour would condense on the surface; and as, at this early period, the thickness of the crust was probably inconsiderable, and it

would therefore be comparatively little broken up into heights and hollows by the earlier eruptions of the vapours from beneath, these, on condensing into water, would probably cover the entire solid surface. It may accordingly be fairly inferred that, at a certain epoch in the remote past, the earth consisted of a solid crust completely covered with water, and containing within it the great mass of the globe in a state of igneous fusion.

That epoch was probably separated from the present time by an immense interval. From a calculation based on the rate of increase of temperature found in descending through the strata, Professor Sir William Thomson of Glasgow has shown that, supposing the temperature of the molten globe to have been about 7000° F., it is improbable that it can have cooled down to its present temperature in less than 20,000,000 of years, or that the period when it began to cool was more remote than 400,000,000 of years ago. In the former case, the underground heat would probably have been higher than the highest, and in the latter case lower than the lowest limit of its present ascertained amount. He further shows, in accordance with a conclusion previously attained by M. Fourier, that the high initial temperature of the earth, or the vibratory motion which constituted that temperature, could not have proceeded from any causes now in operation; and indeed could not have resulted by mere natural processes from any prior condition of matter, but that it must have been produced by a power able to modify the present laws of dead matter, or to originate its laws.[1] This conclusion agrees with the views, respecting the cause of that primary temperature and the manner of its production, given in this and the two foregoing chapters.

Assuming then that, at some remote epoch in the past,

[1] *Trans. Royal Society of Edin.* xxiii. p. 157.

our planet was wholly covered with water, under which lay a solid crust of inconsiderable thickness, containing the remainder of the materials of the globe in a molten condition, it may be fairly supposed that the separation of the land from the water was effected by the gradual operation of the still subsisting laws. The appearances presented by the older rocks render it probable that this operation was accomplished chiefly by volcanic or other subterranean agency, which operated by elevating certain portions of the solid land and depressing others; but the phenomena do not clearly indicate whether these changes occurred suddenly, or by slow degrees, according to their observed progress at the present time. The fluids still charged with much mineral matter, appear to have retired into the hollows thus formed, leaving a large portion of the surface dry, which in due course of time, became gradually covered with vegetation, preparatory to the introduction of the animal kingdom.

There is nothing in the discoveries of geology to contradict this order of events; for they render it probable that even the most ancient of the stratified rocks, which fall under the observation of the geologist did not form any portion of the primary dry land which appeared on the first gathering together of the waters. The rocks which composed the earliest continents and islands probably underwent great changes from their original condition. Their surfaces must have first undergone that disintegration from the effects of air and moisture which is termed weathering, to prepare soil for the vegetation. This process takes place very slowly, and must consequently have occupied a long time. It is probable moreover that the whole or a large portion of the rocks, which composed the first dry land, were afterwards altered by heat. The oldest strata exposed to our observation exhibit evidences of their having undergone such alteration, and

are therefore termed by geologists metamorphic. Many of those rocks which are now regarded as primary may even have been of later formation than the metamorphic rocks, and may have been the instruments employed for further elevating portions of the already existing dry land, while other portions of it may have become again submerged. Hence the discovery of traces of organic substances and forms in some of the so-called primary strata does not prove that the very earliest crust of the earth may not have been destitute of organic life.

Dr. Daubeny made some experiments to determine whether some of the older members of the slaty rocks contain such an amount of phosphoric acid as to indicate the existence of organic beings during their deposition. His method was to prepare soil from those rocks and sow barley in it. The general result was, that the older the rock the less phosphoric acid it supplied to the barley; while the oldest slates which he tried yielded no appreciable quantity. This negative result is so far important; for while the existence of phosphoric acid would not have proved the presence of organic substances, seeing this acid occurs in purely mineral combinations; yet its absence proves the rarity at least of organic bodies, at the time of the deposition of those slates.

The recent discovery however of animal organic remains in the Lawrentian system of rocks in Canada, which belongs to the oldest known series of stratified formations, indicates that none of the stratified rocks now exposed to our observation existed at the first appearance of the dry land. The circumstance that the earliest organic remains yet found in the strata are animal will be more fully considered in the sequel.

The epoch during which the dry land was thus in course of separation from the water was probably one of immense duration; and in the course of it the conditions

of climate would appear to have been very different from what they are now—in so much as to leave it an open question, whether or not the temperature of the earth's surface was at this period derived from the rays of the sun.

The doubt on this point is raised by the nature of the fossil remains of the primæval vegetation, the characters of which, in the opinion of the most able naturalists, indicate the prevalence, for a long period, of an uniform moist climate of equably warm temperature over the entire globe; for these remains present a striking uniformity of aspect under every latitude, and in every quarter of the world. The almost tropical character of the earliest vegetation moreover tends to establish a probability, that it flourished at a period when the increase of temperature in descending through the strata was more rapid than it is now; so as to render the general independent heat of the soil considerably greater than what prevails at the present time—the fossil vegetation being such as thrives best in a reeking soil.

If, following the indication given by this character of the earliest fossil vegetation, we conclude that, while it flourished, the soil was in itself warmer than it is now, and the rate of increase of heat in descending through the strata considerably more rapid, this circumstance would place the period, when the earth first became covered with vegetation, at a very remote distance in the past. For Professor Sir William Thomson has shown it to be probable, that it has required nearly one hundred millions of years to reduce the rate to its present average amount of about one-fiftieth of a degree F. per foot, from about a tenth of a degree per foot in descending through the strata.[1] But an increase of 1° F. in descending

[1] *Trans. Royal Society of Edin.* xxiii. 164.

through ten feet would indicate a general warmth in the soil, hardly sufficient to account for the nearly uniform tropical character of the first vegetation. The period when it flourished must therefore, according to this mode of estimating it, be regarded as more remote than one hundred millions of years. But this vast period will not appear too long, when it is considered that the entire mass of the sedimentary strata, including those which have been subsequently altered by heat, have most probably been deposited since the earliest land vegetation flourished, seeing the very oldest of those rocks have been found to contain embedded animal remains.

CHAPTER V.

THE HEAVENLY BODIES—THE MOON.

From what has been said respecting the manner in which the Terraqueous Globe was probably formed, it may be fairly inferred that those of the heavenly bodies which resemble it in constitution, were consolidated in a similar way, and by the operation of the same laws. To this general conclusion, however, there must be recognised some remarkable exceptions—more especially in the case of the sun, together with all the other central luminaries in the universe. The constitution of those bodies seems to be so very diverse from that of our own globe, that the manner in which their materials were accumulated and arranged may also have been very different. It is, therefore, advisable to consider the constitution of the sun and its probable mode of formation, separately and more at large.

But even the moon, judging from the aspect which it presents when viewed with the telescope, differs so much from the earth, as to require separate consideration. The chief design, which our satellite appears to have been intended to subserve, is that of acting as a subsidiary source of illumination to the earth, and as a great time-piece to mark by its changes the times and the seasons. At least astronomers have not yet been able to discover any other probable purpose in the economy of nature, which it may be designed to fulfil; for it appears to be wholly unsuited to be the habitation of any organic

beings, such as those with which we are acquainted. The most careful surveys with the telescope have failed to detect any traces of a lunar ocean, or indeed of any collection of water whatever, on that half of the moon's surface, which alone is ever presented to our view.

Her possession of an atmosphere again appears a more doubtful point, the evidence seeming to be somewhat contradictory. When stars pass behind the edge of the moon, they generally appear quite sharply defined, till the moment of their being wholly hidden by her disc. This fact shows their light to be not affected to any appreciable extent by a lunar atmosphere. At times, however, stars have been observed to linger on the moon's limb, as if adhering to it for a few seconds before occultation—so raising a suspicion that their light is occasionally affected by a refracting medium of small extent. This probability is strengthened by the recent discovery of a small thread of twilight on the dark edge of the moon, which, on careful measurement, has been supposed to indicate the existence of a lunar atmosphere about a mile in height, and possessing a very small refractive power—nearly 1400 times less than that of the earth's atmosphere. Whence, if the density correspond to the refractive power, the moon's atmosphere, supposing it to have one, will not be denser than that of the earth at a height of between forty and fifty miles.

From this circumstance some philosophers have inferred that the temperature of the moon's surface may be exceedingly low, and that she may possibly be covered with snow and ice. This notion is founded on the fact, that the entire surface of the moon, presented to our view, is placed in the same relation to the sunshine as are the highest portions of the earth's surface, which are covered with perpetual snow. The aspect of the moon, when viewed through a telescope, lends some countenance

to this idea: for it appears as if composed of frosted silver.[1]

Sir John Herschel found vertical sunshine at the earth's surface to be capable of melting 2·7 inches of ice per hour. This quantity accumulated for 14 days continuous sunshine would amount to a thickness of about 77 feet. Could the surface of the moon then be supposed to have a continuous coating of ice and snow about 100 feet in thickness, it would be perpetual. What would be melted in one fortnight would be frozen again in the next; and as the water would continually sink below the level of the ice, our satellite would always present a frozen surface. Any moisture evaporated into its small atmosphere would immediately on its losing the sun's rays, be again deposited as snow or hoar frost.

In a letter addressed to the 'Geological Magazine' for February, 1866, Mr. S. Birch has discussed this question. Having made a careful comparison of the stereoscopic pictures of the moon with those of the snow-covered Alps, he has found a resemblance between the photographic effects produced by the latter, and those presented by the former so remarkable, as to have led him to the conclusion, that by far the greater part of the luminous effect produced by the moon, is due to reflection from snow.

That our satellite has a great reflective power, such as might be exerted by ice or snow, is evidenced by its reflecting back the small amount of light which it receives by reflection from the earth. This phenomenon is observed when only a small portion of the new moon is visible. All the rest of her disc is then occasionally seen to be faintly luminous, an appearance popularly known as the old moon in the new moon's arms.

[1] This whiteness seems to have struck the ancient Hebrews, who named the disc of the moon '*libanah*' (לבנה)—a name derived from a verb signifying to whiten.

The notion that the moon's surface is snowclad, were it admissible, might, perhaps, to some extent, explain the observed absence of heating power in the lunar radiation. For were the entire surface of the moon much colder than that of the earth, the radiation of dark heat would be continuously from the earth to the moon, so that the luminous lunar rays would be unaccompanied by rays of dark heat. It appears more probable, however, that the absence of heat in the lunar radiation is chiefly, if not wholly, owing to the intrinsic feebleness of the heating power of the solar radiation in comparison with its brightness, of which evidence will be adduced in a future chapter. The idea, moreover, of the moon's having a snowclad surface cannot be regarded in any other light than as a mere conjecture.

Putting aside these merely speculative views, there is one point upon which there seems to be no reasonable doubt whatever. That portion of the moon's surface, which alone is ever subjected to our examination, presents evidences of volcanic action on a scale of grandeur far surpassing aught discovered on the surface of the earth. Mount Etna, one of the greatest of terrestrial, would be reckoned among the least of the lunar volcanoes. The craters of the latter frequently occupy vast tracts, from which radiate in all directions long ridges, exactly resembling the solidified streams of lava, emanating from the volcanoes of our own globe. From the central parts of the craters also are often seen to arise cones, like those of Etna, Vesuvius, or the Peak of Teneriffe. Of volcanic action's being in progress on the surface of the moon at the present time, no distinct proofs had been obtained till very recently. From observations made towards the end of 1866 and beginning of 1867 however, it would appear that a conspicuous crater, which had been named Linné, has now been partially filled up, thus indicating that

volcanic action has lately been going on in that region of the lunar surface.

Several of the lunar mountains equal, or even exceed in height the loftiest summits of the Himalayas; so that in proportion to the size of the two orbs, the terrestrial mountains are far surpassed by those of the moon. These characteristics of the lunar landscape must give it an aspect so rugged and barren, as to indicate that, as regards its hither side, at least, it is not at all adapted to sustain organic life, consequently that its main design is to serve as a subsidiary luminary, and an unerring celestial time-piece to the dwellers on the face of the earth.

With the conspicuous powers of reflecting light exhibited by our satellite, either an ocean or a large and dense atmosphere would have seriously interfered. But while the absence of those elements, so needful to organic life, prevents our regarding the moon as fitted to be the abode of organized beings, it increases our admiration of the wise provisions, by which the main design of furnishing a sub-sidiary luminary to the earth is secured. This admiration is enhanced when we attend to her motions, which are in a peculiar manner adapted to the measurement of time.

The general aspect which the moon presents to an observer on the earth is best illustrated by M. De la Rue's stereoscopic photographs. From a microscopical examination and measurement of those pictures, M. Gus-sen, a Russian astronomer, has drawn the inference that the moon is of the form of an egg, having its smaller end turned towards the earth. But this figure is so dissimilar to that of the other celestial bodies, which are all flattened spheroids like our own globe, that great caution must be observed before accepting this conclusion.

Founding on certain minute anomalies detected by Professor Airy in the moon's motion, M. Hansen sug-gested that the two hemispheres of our satellite may be

of unequal density, that which is constantly turned towards the earth being the lighter. This view has been generally accepted as explanatory of the observed anomalies. But while such an inequality of density is consistent with M. Gussen's notion that the hemisphere next the earth bulges out like the smaller end of an egg, it does not of necessity involve that idea. The moon may, like the earth, be a true oblate spheroid of revolution, flattened at the poles and protruding at the equator, yet have one hemisphere specifically heavier than the other. As to any conjectures, founded on this inequality or the supposed egg-form, with respect to the moon's having an ocean and an atmosphere on its averted side, and there only, such must ever remain in the darkest regions of speculation.

With respect to our greater luminary the sun, the most recent discoveries tending to illustrate the constitution of that glorious orb, and the theories which have been propounded for explaining the phenomena which it presents, are so interesting in themselves, and have so important a bearing on the general subject of this treatise, as to render it expedient to consider them somewhat at large.

CHAPTER VI.

THE SUN—HIS GENERAL ASPECT.

The surface of the sun, when viewed through a properly guarded telescope, is seen to be not uniformly luminous. It presents a more or less mottled and changeful appearance, indicating a state of constant activity. In addition to this mottling, and usually where it is most abundant, there frequently appear spots of various forms and sizes, some of them of very large dimensions. These, after continuing for a while, gradually disappear.

In every perfect spot there may be distinguished 1st. the nucleus, which appears quite black. It occupies the central part of the spot, and has a somewhat rounded outline. Surrounding the nucleus, and spreading over a much larger space is the umbra, which, though very dark, is not, like the nucleus, absolutely black. Its exterior outline is sharply defined, irregular and jagged. This outline separates it from the penumbra, which is of still greater extent and is self-luminous, but not nearly so bright as the general surface of the sun. It has a somewhat radiated appearance, the rays pointing towards the umbra. It is separated from the general luminous surface or photosphere, by an outline, which, though less sharply defined than that which separates it from the umbra, is yet distinctly marked, and presents the same jagged and irregular appearance.

In imperfectly developed spots, the nucleus is wanting and in some both nucleus and umbra are absent. These

last are generally spots which are in the course of fading away. On the other hand, spots are sometimes seen without a penumbra; but these are generally in the course of formation. Occasionally the spots are either wholly or partially bridged over by a brilliant band of luminous matter, at least as bright as the general surface of the photosphere, but sometimes appearing still brighter, perhaps by contrast with the darkness of the umbra.

The form and general aspect of the spots are for the most part exceedingly fantastic, especially where numerous spots are crowded together. In such a case it frequently happens that there are several umbræ, with or without a nucleus embedded in one continuous penumbra.

There are also sometimes observed on the surface of the sun what are termed faculæ. These are accumulations of the luminous matter of the photosphere, more dazzling in their brightness than the general surface. They are usually found in the neighbourhood of the spots, but are sometimes, though rarely, seen where no spot exists. They occur more frequently near the edge than towards the centre of the disc, but never in the polar regions of the sun.

Improved appliances have enabled observers to analyze, as it were, the general aspect of the photosphere itself. Mr. Nasmyth was the first to point out that the mottled appearance is caused by the superposition of luminous bodies, having all nearly the same uniform shape, closely resembling that of a willow leaf. Other observers have likened them to grains of rice. More recently Mr. Nasmyth has distinguished four gradations of form—the long-pointed willow-leaf shape being the one extreme, while the rice-grain shape is the other. The first kind occupies the penumbral regions of the spots; and the jagged outline of the penumbra is caused by the points of these

forms being all directed inwards towards the umbra, or outwards towards the photosphere. The two intermediate forms are found in the bridges, the longer and narrower occupying the central parts, while the shorter and wider are seen nearest the extremities where the bridges join the photosphere. This last kind, together with the shortest of all, the rice-grain forms, characterize the photosphere itself. In the case of the bridges, these forms generally lie in the direction of the bridge; but in the general photosphere they are huddled together—heaped one upon another in complete disorder, and lying in all possible directions. They are also in a state of perpetual movement. The average size of these bodies Mr. Nasmyth estimates at about 1,000 miles in length, by about a tenth of that extent in breadth.

The Rev. Mr. Dawes, on the other hand, differs somewhat from Mr. Nasmyth in his description of the photosphere. He says it is composed of luminous masses of all shapes and sizes, whose outlines are marked by minute dark dots, which are separated one from another by small luminous spaces, having a brightness about equal to that of the penumbra of a spot. This outline he affirms to be almost always thus interrupted and very rarely continuous. While admitting the existence of the long-pointed forms described by Mr. Nasmyth, he declares them to be of much less frequent occurrence than the other irregular forms with dotted outlines, and he regards them not as distinct masses of definite form, but as ripples, waves or ridges in the luminous stratum.

Differences in the modes of observation and in the instruments employed may partly account for this diversity of description. Mr. Dawes uses a very minute aperture for his eye-piece, and it has been suggested that the appearances seen by him may be in some measure due to the effects of diffraction arising from this cause. Other

observers testify to having seen the same appearances as those described by Mr. Nasmyth. The two descriptions, moreover, are perhaps not so irreconcilable as they at first sight appear. Mr. Nasmyth admits that the forms he describes are most clearly perceptible in the penumbra and bridges, where they have more or less of a definite direction and distinguishable outline; while in the general photosphere they are huddled together in a confused mass. But rice-grain shaped bodies, thus heaped one upon another, might present very much the same general appearance as the masses with dotted outlines described by Mr. Dawes. Numbers of them might be apparently so closely packed together, and in so many layers at particular points, as to look like one large luminous clump; while the dotted outline might be caused by the protruding ends of the rice-grain forms, projected on a less luminous ground. It is only where these brilliant bodies are disposed as in the penumbra in a thin layer, or as in the bridges in right lines, that their true forms can be expected to be distinguishable. It is affirmed by some observers that the rice-grain shaped bodies themselves undergo individually slight modifications of outline.

The persistence of some of the spots for a considerable time has rendered evident their apparent motion across the solar disc in one uniform direction. This motion has led to the inference that the sun rotates on his axis, and has enabled astronomers, on this assumption, to determine the probable position of his equator and poles. It has thus been ascertained that the spots are confined to a region extending to about 50° on either side of the sun's equator. No spots have been ever observed in a higher latitude; and their occurrence so far north or south as 50° is very rare. The region in which they most frequently appear lies between 8° and 20° north or south of the solar equator. They are more rare in the equatorial

region between 8° north and 8° south—rarer still between 20° and 50° north or south. When numerous, the spots generally lie in lines nearly coincident with the parallels of latitude—which are in the direction of their apparent motion, but occasionally somewhat oblique to them. There is however no line of longitude in which they appear more frequently than in any other; so that their cause, whatever it may be, has no fixed locality on the solar surface.

When, in consequence of its apparent motion, a spot draws near the margin of the sun's disc, it gradually narrows, and disappears before reaching the limb. The nucleus and umbra first dwindle to a mere thread and then vanish. The penumbra continues visible for a while thereafter, gradually becoming narrower, but also disappearing finally before arriving at the extreme edge. The same appearances are generally presented by the faculæ, on their approach towards the margin. Thus it happens that, notwithstanding the great diversities of elevation on the surface of the sun indicated by the spots and faculæ, the solar disc is uniformly quite smooth and sharp—presenting an uninterrupted circular outline.

Very rare exceptions, however, to this uniformity have been noticed. Several observers, among others Mr. Dawes and Mr. Howlett, have remarked one or two instances of faculæ, which, on approaching the limb, appeared to project slightly, like a ridge, beyond the circular outline.

M. De la Rue has taken numerous photographs of solar spots, and in particular two views of one large spot, for the purpose of being conjoined in the stereoscope. When viewed in this instrument, the spot has the appearance of a vast deep cavern.

Some spots, particularly those of large size, undergo great and occasionally very rapid changes of appearance,

evincing immense activity in the materials by which these appearances are presented. The umbræ of some spots have been observed to rotate slowly on their centres. When a spot first begins, it usually has its origin in an enlargement of one of the small dots before mentioned. This forms the nucleus. As it expands it becomes surrounded by the umbra, which gradually increases in size. After the umbra has attained a certain magnitude, it becomes surrounded by the penumbra, which in like manner gradually augments in area. On the other hand, when a spot begins to disappear, the umbra usually becomes divided by one or more luminous bridges. The umbræ thus separated diminish in size, and finally close up; but the penumbra lingers for some time, gradually lessening in its dimensions until it also ultimately disappears. In some instances the bridges fade away into penumbral shade, and become subsequently overlapped by others. The order of these changes seems to indicate, that the effective cause of the spots is of the nature of an upheaval of the lower non-luminous strata.

It has been mentioned that the spots appear to move in one direction across the solar disc, whence the sun's rotation on its axis has been inferred. It so happens, however, that observations made on different spots, give diverse periods for this rotation. Mr. Carrington has ascertained that the rate has a certain dependence on the position of the spot, with reference to the sun's equator. If a spot lie immediately over this line, it indicates a rotation in 24·97 days. Should the spot be at the extreme observed distance from the equator of 50°, the rotation is in 28·36 days. In intermediate positions, the periods appear to be of intermediate lengths—following a certain law.[1] Sup-

[1] To this law Mr. Carrington has given expression in the following formula:—The diurnal rotation in longitude $= 865' - 165' (\text{sin. lat.})\ \frac{7}{4}$. Sporer gives the formula:—$\xi = 16{\cdot}8475^\circ - 3{\cdot}3812^\circ$ sin. $(41^\circ 13') + \text{lat.}$—$\xi$ being the arc described in a solar day.

posing the length of the period to increase regularly, according to this law, from the equator to the pole, it would at the latter point amount to 30·86 days. Professor Fearnley of Christiana, in 1857, observed a remarkable spot which reappeared on the disc three times; whence he deduced periods of rotation in 25·46, 25·67, 25·83, 25·87 and 26·23 days. This increase of period would, according to Mr. Carrington's law, indicate the spot's having travelled farther from the equator at each reappearance.

Such a lateral motion both from and towards the equator has been observed in other spots, but the observations do not clearly indicate in which direction is the general tendency of this lateral motion—whether more towards or from the equator. According to Mr. Carrington, the luminous matter of the sun is affected by lateral currents, besides the motion from which the rotation of the solar orb has been inferred. From about 15° latitude north and south, a current seems to drift from the equator towards the poles; but of this drift the evidence ceases at about latitude 50°. At latitudes lower than 15°, there appears to be an opposite drift from the poles towards the equator. From these movements Mr. Carrington infers that there must be, attendant on each drift, an under current in an opposite direction. He further supposes that the same matter, which drifts in one direction in the upper current, sinks down and returns by the lower; while that which travels by the lower ascends and returns by the upper—a continual circulation being thus maintained.

The circumstance, that the movement of the spots indicates the rotation's being faster at the equator than at the poles, proves that these spots and the luminous material generally must exist in an envelope, surrounding the body of the sun; for no solid substance, or molten material constituting a globe, could exhibit such a variation in the rates of motion of its poles and its equator. A spheroid,

having any degree of consistency, would have the same period of rotation for all parts of its surface.

Another remarkable circumstance attending the solar spots is their periodicity. There are certain years in which the spots are so few, that periods of many days or even some months may elapse, during which the surface of the sun is immaculate. Other years are distinguished by the remarkable abundance and great size of the solar spots. The minima, or times of least spotting, are found to occur at regular intervals of a little over eleven years; so that there are about nine recurrences in a century. The maxima follow a similar law; but their recurrences are less easily marked, because it is somewhat difficult to decide upon the amount of spotting, which may be regarded as the greatest. A maximum, however, does not occur exactly midway in point of time between two consecutive minima, but rather earlier, at an interval of somewhat more than four years and a half from the preceding minimum. Besides this simple alternation of maxima and minima, there is another of longer period. The differences in degree between the greatest and least amount of spotting are found to fluctuate to a considerable extent—becoming at one time nearly double of what they are at another. The period of this fluctuation is about five times that already mentioned, or nearly fifty-six years. There is also a shorter period of variation less distinctly marked than those other two. Taking an average of years, spots are more frequent from September to January than during the rest of the year. When the period of least spotting approaches, the spots become mostly confined to the equatorial zone; but after the minimum is passed, they reappear most abundantly in the latitudes lying beyond the limits of that region.

There is a remarkable coincidence between the periodicity of the solar spots, and that of the increase and decrease

in the mean annual amount of variation in the declination of the magnetic needle. This variation is greatest when the sun is most spotted, and least when the sun is immaculate—the increase and decrease following the same period of about eleven years. Even the longer period of fifty-six years seems to be represented in the magnetic variation.

Precisely the same law affects the frequency of the appearance of the Aurora Borealis—its maxima and minima corresponding to those of the solar spots, both as respects the short period of eleven years, and the longer of fifty-six.

That there is some intimate relation between solar phenomena and terrestrial magnetism is further evidenced by a remarkable occurrence separately observed, September 1, 1859, by Mr. Carrington at Redhill and Mr. Hodgson at Highgate. These gentlemen, happening to have their telescopes directed towards the sun at the same moment, observed two luminous bodies, whose brightness exceeded that of the general surface of the photosphere, and which appeared to traverse together the central portion of the solar disc with enormous speed. After first waning in brilliancy, they gradually faded away, and at the end of about five minutes were quite lost to view. It was subsequently ascertained that, in all the observatories throughout the world, the magnetic needle had been disturbed to an unusual extent, at the moment of this singular occurrence. This circumstance raises a probability of the observed phenomenon's having been of the nature of an electrical discharge on an enormous scale. Of the surface of the sun's being in a state of perpetual electrical excitement, there is strong evidence afforded by its effects on comets, as they approach the luminary. It is then observed that there is a powerful repulsive force exerted on certain elastic materials, forming a large portion of the

bulk of comets. This repulsion effectually prevents any comet, which in its perihelion passage approaches very near the sun, from actually falling into it; for it counteracts the force of gravity, and aids the centrifugal force in driving the comet away on its outward journey. So powerful is this repulsive force, that it has been known to separate one portion of a comet from another. This happened in the case of Bielas's comet, which was cleft in twain during its perihelion passage. Sir John Herschel is of opinion that it also similarly affects the celebrated comet of Encke, and at each perihelion passage separates a certain portion of its elastic substance from the main body of that comet, which thereafter pursues its course in a diminished orbit. This view is confirmed by the circumstance that, at each reappearance, Encke's comet seems to have dwindled in size. For such a repulsive force, exerted by the surface of the sun, it would be difficult to account on any other supposition than that of its being due to an accumulation of electrical tension.

Another remarkable solar phenomenon is that of certain rose-coloured prominences observed when the sun is totally eclipsed. These make their appearance immediately after the moon wholly obscures the solar disc. They project to an estimated average distance of forty or fifty thousand miles from the edge, while some extend even as far as seventy thousand. In certain instances a clear space, of several thousand miles in extent, can be distinguished between the red prominences and the limb of the sun—a fact rendering it not improbable, that these bodies may exist in a shell of gaseous matter surrounding the sun, but having no material connexion with his photosphere, from which it may be separated by a considerable interval. Only those prominences which happen to be immediately over the edge of the disc, or nearly so, can be seen thus detached from the limb; all others more remote from the

edge would appear as if touching the disc. This idea that the elastic medium, which supports these rose-coloured masses, may possibly constitute a shell completely enveloping the sun, but at some appreciable distance from his luminous surface, with an intervening void space, is consistent only with the supposition that the electrical repulsion manifested in the case of comets acts also on this shell, and at the distance at which it is placed establishes an exact counterpoise to the force of gravity exerted by the solar mass; so that the shell can neither approach the sun by reason of gravitation, nor recede from it under the influence of the repulsive force.

The moon gradually covers the red prominences on the side towards which she is advancing, while uncovering them on the side from which she is departing. This circumstance proves these bodies to be in the immediate vicinity of the sun. All doubt on this point has been removed by the photographic impressions of the sun's disc obtained during the total eclipse of 1860. One set of these impressions was taken by M. De la Rue at Desierto de las Palmas, the other by Señor Aguilar at Miranda, both in Spain; the distance in time between the two stations being seven minutes. On careful comparison, these two impressions exhibit an agreement so perfect, as to show the distance of the rose-coloured prominences from the earth to be such that they must be quite close to the sun.

Some astronomers have inferred from this phenomenon, that there is a rose-coloured stratum overspreading the whole of the sun's luminous disc. But this view is discountenanced by the partial distribution of the prominences actually observed, by the clear space which separates some of them from the limb, and also by the circumstance that M. De la Rue's photograph exhibits a prominence which was not visible to the eye, and which may therefore be inferred to have belonged to the violet end of the spec-

trum, whose light might have been too feeble to affect the eye, although exerting a strong photographic power.

The brightness of the prominences is estimated by M. De la Rue at about 900 times less than that of the general surface of the solar photosphere, and as not exceeding that of the umbra of a spot. Unlike the spots, which are confined to a definite region on either side of the sun's equator, the red prominences appear indifferently on every part of the solar limb. Messrs. Lockyer and Janssen have succeeded in subjecting the light of these prominences to spectrum-analysis, and have ascertained that by a little skilful management their spectrum can be detached from that of the photosphere, even when the disc is not under eclipse. The spectrum exhibited by the prominences corresponds to that shown by hydrogen gas, when rendered incandescent by an electrical discharge. The conclusions deducible from these observations are—1st. That the prominences are probably produced by incandescent hydrogen. 2nd. That the incandescence is in all likelihood caused by electrical discharges passing through a hydrogenous medium—the rapid changes of appearance and amazing velocity of apparent motion exhibited by the prominences being due to the play of the electrical discharges. 3rd. That the hydrogen probably constitutes a gaseous envelope surrounding the sun, at some distance from the surface of the photosphere, and separated by an interval of free ether. This last conclusion follows from the law of the diffusion of gases; for a layer of hydrogen could not remain isolated, were it in contact with an atmosphere of any other kind of gas, seeing it would become diffused through the other. As there seems to be little doubt that the luminous bodies of the photosphere are floating in a gaseous atmosphere, the existence of a free interval between it and the outer envelope of hydrogen is highly probable. Mr. Lockyer has proposed to name this hydro-

genous envelope 'the chromosphere,' and he deems it to be of comparatively inconsiderable thickness, estimating it roughly at about 5,000 miles.

That this chromosphere exerts a certain amount of absorptive power on the sun's light passing through it, and especially on the violet or photographic rays, is proved by the fact that in photographic images of the sun, the intensity of the picture increases from the margin towards the centre. It has also been ascertained by measurement, that the general illuminating and heating powers of the sun decrease from the centre to the circumference. Part of this effect is perhaps due to the fact of the circumference of the solar disc's being more distant than the centre; but it seems probable that it is in part owing to the circumstance that the light near the edge of the disc, having to traverse a greater thickness of the medium in which the red prominences float, undergoes in the course of that journey a considerable amount of absorption, more especially of its photographic rays.

That the solar radiation, after leaving the immediate surface of the photosphere and before reaching the earth, is subjected not only to a general, but also to a special absorptive action, is rendered manifest by another remarkable phenomenon. It is well known that when light is transmitted through a glass prism, the image becomes extended in one direction, forming a coloured spectrum of seven tints, red, orange, yellow, green, blue, indigo, and violet. When the prism is made of rock-crystal instead of glass, and the spectrum is received on a surface prepared with the disulphate of quinine, the image becomes still more extended towards the violet end, rays being thus rendered visible which are invisible under ordinary circumstances. Now the appearance of this spectrum depends greatly on the source whence the light emanates. If it proceed from a purely incandescent

source, that is, from a body raised to a white heat, the spectrum is continuously luminous throughout its whole extent. If it proceed from the sun, it is quite otherwise. The solar spectrum is interrupted by many thousands of dark lines, some few of them very conspicuous, but the majority of such extreme fineness as to be detected only under high magnifying powers. These lines always retain a fixed position relatively to each other, when the prism is formed of the same substance, and are named from their discoverer the fixed lines of Fraunhofer. If the light passed through the prism be that of a flame, on the other hand, it is found to present a totally different aspect, depending entirely on the nature of the substances which contribute to form the flame. It has been ascertained by Messrs. Bunsen and Kirchhoff that every chemical element, when thrown into vapour and in this state made to give out light, produces a characteristic spectrum of its own. Most of these elements present in their spectra one or more bright lines, while the rest of the image is either comparatively feeble or quite dark. But if light either from the same or from another source pass through any such heated vapour, the bright line or lines, which would be formed by the glowing vapour itself, will be obliterated, and replaced by a dark line or lines occupying the same position.

For example, if the metal sodium be introduced into the flame of a spirit-lamp or of hydrogen gas, both of which give very feeble spectra, there will be seen a brilliant yellow line occupying a position near the limits of the yellow and orange in the common spectrum. This is termed the sodium line, and is an infallible test of the presence of that metal even in the most minute quantity. On the other hand, if the light from an incandescent source, such as a white hot platinum wire, be transmitted through the vapour of sodium, the spectrum from the in-

candescent light, which would otherwise be continuous, is interrupted by a dark line, occupying the exact position of the bright sodium line in the other case. When the light from the sodium flame is itself transmitted through sodium vapour, this dark line appears with still greater intensity. Similar phenomena are presented by all the other elements. Hence it appears that while every element in the state of vapour, which enters into the constitution of a flame, produces one or more bright lines in the spectrum, that same vapour will produce black lines occupying the same positions when the light passes through it. Each vapour absorbs in their passage the same definite rays which it produces when itself giving forth light.

Now M. Kirchhoff ascertained that the dark line produced in the spectrum, when the light from an incandescent body passes through sodium vapour, occupies the exact position of a conspicuous dark line in the solar spectrum, which Fraunhofer had designated by the letter D. Proceeding further, he found that the lines, produced by several other elements in the state of vapour, correspond exactly in position with certain other dark lines in the solar spectrum. Among the elements yielding this result, in addition to sodium, are iron, calcium, magnesium, chromium, and several others. Conspicuous by their absence are the lines produced by the vapours of silicon and aluminium—elements which enter so largely into the composition of the terrestrial globe.

From these observations the legitimate conclusion is, that certain of the dark lines found in the solar spectrum are produced by the solar light's having, on its journey from the photosphere towards the earth, passed through vapours of the elements sodium, iron, calcium, magnesium, chromium, &c. But it by no means follows that those vapours constitute any portion of the solar orb, or

an atmosphere immediately surrounding the photosphere and in contact with it. They may exist at any distance from the sun where the heat is sufficiently strong to maintain those elements in the vaporous condition, and that distance may be considerable.

While solar light differs from that proceeding from an incandescent body, in as much as it exhibits an interrupted instead of a continuous spectrum, it differs in another important particular. It has less heating power in proportion to its brightness. Thus, when the radiation from the sun, and that from lime heated to whiteness by the oxhydrogen blow-pipe are both received on the blackened bulb of a thermometer, it is found that, for equal degrees of brightness, and after making full allowance for the absorptive effects of our atmosphere on the solar rays, the radiation proceeding from incandescent lime is upwards of four times more effective in producing heat than is that from the sun.[1] This fact leads to the conclusion either that the solar radiation differs in kind from that produced by incandescence, or else that it loses a very large proportion of its heating power during its journey from the photosphere towards the earth's atmosphere. Of these two suppositions the latter seems the less probable. The dark lines of the solar spectrum may be considered as the measure of the absorption which sunlight undergoes before reaching the earth. Now these, although so exceedingly numerous that, when viewed through Prof. Cooke's large spectroscope, they may be deemed almost innumerable, yet bear a small proportion in point of space to the luminous bands which they separate. Moreover, their existence lessens the brightness, and it is in proportion to its brightness that solar radiation is deficient in heating power, as compared with that

[1] See note A,

from incandescent lime. The deficiency is also too great to be accounted for by any probable amount of absorption.

In respect of its heating power, solar radiation agrees more nearly with that derived from burning magnesium wire. For equal degrees of brightness, the heating power of the radiation from the magnesium flame appears not to exceed that of the solar rays; it is consequently very inferior to that of the radiation from incandescent lime. This circumstance favours the conclusion that the solar radiation differs in quality from that of an incandescent body, and shows that the brightness of any radiation is no measure either of the temperature at which it may be generated, or of the heat which it can excite.

The solar radiation also appears to differ in quality from that of the electric light. The length of the visible solar spectrum is the same as that produced by the light from incandescent lime; but the visible spectrum from the electric light extends considerably farther than the solar spectrum at the violet end. This difference is seen most conspicuously in the enlarged spectrum, obtained when the light is passed through a prism of rock crystal, and received on a screen charged with disulphate of quinine. It is possible, however, to explain this comparative shortness of the solar spectrum by supposing the extreme violet portion of it to be absorbed during the passage of the radiation through the elastic medium which sustains the red prominences. The colour of these affords evidence that the absorptive action of that medium is exerted more on the rays at the violet end of the spectrum than on those at the red. The difference in the lengths of the solar and electric spectra is therefore not conclusive evidence against the ultimate identity of the two species of light.

As regards the absolute brightness of solar light, when compared with a terrestrial standard, as determined by the

eye, it has been found that, when contrasted with that of incandescent lime heated by the oxygen and coal-gas blow-pipe, the intensity of the illumination at the surface of the sun is probably about 7,000 times greater, area for area.[1]

It is difficult to compare the electric light with that of the sun; because the former varies so much in intensity with the strength of the battery employed. From a series of fifty cells of Grove's battery, the light obtained may be about three times the brilliancy of the lime light above mentioned. But from a battery of 250 carbon elements, each with an active zinc surface of eighty-five square inches, Professor Rogers has obtained an electric light which, according to his description of it, would appear to have been fifty times brighter than the lime light—consequently only 140 times less intense in brilliancy than the surface of the solar photosphere. This, however, must be regarded as a somewhat loose estimate.

The quantity of light and heat received from the sun by the earth has remained constant during the whole of the historic period. This is proved by the circumstance, that the mean temperature of Palestine, which occupies a centrical position on the earth's surface, has continued unaltered since the days of Moses, who records that the vine and the palm-tree both flourished there in his time as they do still. Now that both dates and grapes may ripen in the same country, its mean temperature must lie between 70° and 72° F. This is the mean temperature of Palestine now, and it must have been the same in the time of Moses. Moreover, a variation to the extent of 1° F. would alter the earth's radius by about a two hundred thousandth part of its amount. But from recorded eclipses it appears that during the last 2,500 years, the

[1] See note A.

earth's radius cannot have altered by a hundredth part of this amount—consequently, the mean temperature of the globe cannot have altered a hundredth of a degree during that time. There is, therefore, no evidence whatever of any appreciable abatement in the amount of light and heat derived from the sun, so far as human annals extend.

Such is the array of facts and phenomena which must be kept before the mind, in any attempt to form conjectures regarding the constitution of the sun—the nature of his light, or the manner in which the supply is maintained.

CHAPTER VII.

SOLAR SPOTS AND FACULÆ.

To ARRIVE at any conclusions respecting the constitution of the solar photosphere, it is needful to direct attention first of all to the spots and faculæ. And here two views present themselves. First, the spots may be dark clouds floating over the glowing surface of the sun, and either wholly or partially obscuring his light. Second, the spots may be openings in the luminous envelope of the sun, uncovering portions of his non-luminous surface beneath. Of these two views, the former is maintained by those who regard the light of the sun as being that of a solid or liquid incandescent sphere; but the latter is adopted by those who have most attentively observed the spots and their attendant phenomena.

In M. De la Rue's stereoscopic photograph of a spot, the impression conveyed is that of looking into a deep gulf or cavern; but this appearance may be an illusion. The fact however of a facula, or very bright ridge, having been seen to project slightly beyond the circular edge of the sun and the adjacent penumbra of a spot, is the strongest confirmation of the second view. For to have been visible beyond the edge at all, such a projection must have been of an immense height; and so great a temporary projection from a liquid or solid incandescent surface is in the highest degree improbable. Moreover, its protrusion beyond the adjacent penumbra of a spot proves the more luminous portions of the surface to be

higher in level than the darker, contrary to what they should be were the spots of the nature of clouds floating on the surface. Such floating clouds, on approaching the edges of the disc, would, when of large size, appear as notches—the darkness extending to a sensible distance inwards from the limb. But all spots disappear before reaching the edge; and when they are reduced to a narrow line by their near approach towards the limb, there is always a thread of light lying beyond, and forming the actual edge of the disc. A cloud would require to be of great thickness wholly to obscure a light so intense as that of the photosphere; but the total disappearance of the dark image, before it reaches the limb, is inconsistent with the cloud's having any appreciable thickness. The appearance actually observed is, on the other hand, exactly what would be presented on the supposition of the spot's being an opening in the photosphere. Such evidence as exists, therefore, is altogether in favour of the second view.

According to this view, then, the luminous matter of the sun is to be regarded as floating in a non-luminous and transparent elastic medium, at an immense height above his true surface, while the spots are caused by partial and temporary dispersions of this luminous material. The faculæ again are accumulations of the luminous matter into great heaps, rising above the general level of the photosphere, and on rare occasions protruding beyond the edge. Their augmented brilliancy is due to their being composed of numerous layers of the shining material. In the penumbra of a spot, on the other hand, the luminous substance is thinned to a comparatively small thickness. The umbra of a spot is supposed to be a portion of an elastic envelope of great thickness, intervening between the photosphere and the true surface of the sun, while the nucleus is that surface

itself, which is screened by the intervening stratum from the glare of the photosphere. The umbral region, however, may be regarded as simply a continuation downwards to a great depth of the non-luminous elastic medium, which sustains the luminous matter floating in it. But this lower portion of the medium may have suspended in it dense vapours, which tend to absorb or reflect the light. The darkness of the umbra and nucleus may nevertheless be to a great extent owing to the effects of contrast, and even the nucleus may be really very bright. But there is no proof whatever of its actually having any brightness, beyond what may be due to the light which it receives from the photosphere, and which it may partially reflect. The same may be said of the umbra; there is no evidence that either of these shine by their own light. With the penumbra it is different. Though its brightness is very inferior to that of the unbroken general surface of the photosphere, it is still considerable, and of such a character as to show it to be self-luminous.

From this constitution of the photosphere it appears that, viewed apart from the non-luminous and transparent elastic medium in which it is suspended, it has far from an uniform level surface. On the contrary, it must, at least occasionally, present great elevations constituting the faculæ, and great depressions constituting the penumbræ of spots. How then does it happen that the limb of the sun, except on very rare occasions, always presents an uniform circular outline? This may be accounted for in two ways. Owing to the great distance of the sun, an elevation or depression would require to have a large magnitude, in order to its being appreciable as either a projection or notch on the edge. But besides this consideration, it has been shown by Professor Challis, that

the refractive power of the sun's atmosphere, exterior to his photosphere, may be of such a character as to produce this apparent uniformity of outline. Were the earth viewed from the moon, the actual surface of the globe would be projected beyond its true position, by the refraction of the lower strata of the atmosphere. But the light from the higher mountains, passing only through the rarer regions of the atmosphere, would be little affected by its refraction; consequently the general surface would appear to be proportionally more extended outwards than the mountain-tops, and the outline would seem more uniform than it really is. Now the atmosphere surrounding the solar photosphere may exert a similar action in a greater degree—so elevating the general surface and all depressions, and simultaneously lowering in proportion all projections, as to bring the whole sufficiently near a level, to appear quite uniform at the distance from which it is observed.

According to this view, what we see is not the true edge of the photosphere, but an image of it projected, by the refraction of the exterior solar atmosphere, so far beyond it as to obliterate all irregularities. Its outline will nearly coincide with that of the limiting surface, at which the solar atmosphere ceases to exert sensible refractive power. The rare phenomenon of a facula's being seen to project beyond the general circular outline, may, according to this theory, be rather of the nature of a *mirage*, caused by some great but temporary change in this refractive action of the solar atmosphere, than an evidence of more than usual height in the facula. There may however be required a combination of both causes.

If this theory be correct, and the visible edge of the disc be an image at some distance from the true edge, it would strengthen the probability that the elastic medium,

in which the red prominences float, may be separated from the surface of the photosphere by a considerable interval of free space.

Regarding the spots then as openings in the photosphere, the manner of their formation shows, that the disturbances, of which they are manifestations, take place by upheaval from below. The elastic matter underlying the photosphere becomes from some cause or other expanded; it forces its way through an opening in the cloudy region which constitutes the umbra, enlarging the opening to a considerable extent. In this manner is formed the nucleus, and a portion of the true surface of the solar orb becomes exposed. The rounded outline of the nucleus shows, that the umbral region contains suspended in it large vaporous masses. The elastic matter ascending from below, after forming this opening, seems to expand outwards in all directions, scattering the luminous material and reducing it in thickness. Thus a larger surface of the cloudy region becomes exposed and forms the umbra. Appearing still further to expand in its ascent, the elastic matter seems to sweep over a portion of the photosphere itself, and so to reduce its thickness as to form a large penumbra surrounding the umbra. Moreover the luminous material, thus swept from off the face of the penumbra, becomes heaped up in the marginal portions of the photosphere, and there forms the faculæ, exhibiting a brightness superior to that of the general surface.

When the disturbing force ceases to act, the upheaved elastic matter begins to subside. The luminous material is thus drawn towards the nucleus of the spot, over which it forms a bridge; it then spreads itself over the umbra, dividing it into separate portions, till it becomes wholly obliterated; and finally it overspreads the penumbra itself, the faculæ at the same time losing their superior brilliancy, and the whole area, formerly occupied by the spot, at

length attains the same uniform brightness as the general photosphere.

Such are the conclusions to which Mr. Dawes has been led by his attentive observation of the spots, and their modes of formation and disappearance. In some instances the elastic matter does not penetrate the cloudy region, but seems merely to expand it in volume, causing it to disperse the superincumbent luminous material. There is thus formed first an umbra, and then a penumbra, but no nucleus. Such Mr. Dawes terms shallow spots.

It has been remarked by Mr. Balfour Stewart, on examining the photographs of numerous solar spots taken at Kew observatory, that the faculæ are for the most part accumulated towards the left of the spot—that is, in its rear, the apparent motion of the spot being from left to right. Out of 1,137 cases, 584 had the faculæ thus accumulated on the left, 45 had them on the right, and 508 had them both on left and right; but among these last the larger proportion had them collected more to the left than the right. It must be borne in mind, however, that faculæ are sometimes seen disconnected from any spot.

From the foregoing description it appears that the presence of spots does not materially affect the general brilliancy of the solar disc, but only transfers the brightness from one part of his surface to another. The darkness of the nucleus and umbra, and the faintness of the penumbra, are nearly compensated by the augmented brightness of the faculæ, in which is accumulated all the luminous material swept from off the region of the spot.

Now as regards the cause of the disturbance by which the spot is formed, it cannot be situated in any particular locality on the surface of the Sun itself; for although the spots are confined to certain latitudes on

the solar sphere, they make their appearance indifferently in every degree of longitude. Neither can any particular point of latitude and longitude be fixed upon at which a spot breaks out at successive intervals of time, so as to indicate the existence of any local cause, such as a volcano, at that point, to which the disturbance may be referred. Astronomers have thus been led to look beyond the sun itself for the disturbing cause.

The limitation of the spots to a certain region on either side of the Sun's equator, united to their periodicity, raises a probability that the disturbance may be of the nature of a tidal wave, and have a planetary origin. This view is strengthened by the fact of there being generally a greater number of spots between the months of September and January, than during the rest of the year. For at that period both the Earth and Venus exert a stronger attraction on the solar surface, and may therefore help to cause a considerable amount of tidal action on his elastic envelopes, causing the materials to rise up and expand outwards.

Following this indication, Sir John Herschel has proposed a theory for explaining the spots by a special kind of planetary action. Many astronomers conceive the zodiacal light to be caused by the reflection of the Sun's rays from a vast number of very minute planetary bodies, which form a sort of ring round the Sun. Sir John Herschel supposes the bodies composing this ring to have one with another, a mean periodic time corresponding to that of the maxima and minima of the solar spots; performing nine revolutions in a century. This is a trifle less than the periodic time of Jupiter (11·862 years); so that the entire orbit of the ring would lie within the orbit of that planet, its major axis being a little less than five times that of the Earth. The orbit of the ring Sir John supposes to be exceedingly eliptical like that of a

comet; so that the bodies composing it are, during their perihelion passage, brought very near the Sun, and are there much crowded together; while in their aphelion they become more scattered. It is during their perihelion passage that he supposes them to exert that species of tidal action on the Sun's envelope which originates the spots. By supposing an unequal distribution of the masses composing the ring, he explains the periodic maxima and minima of the spots; and for even the longer period of fifty-six years, when the difference between the maxima and minima attains its greatest amount, he accounts by supposing the recurrence at such intervals of certain arrangements of the masses, by which they act more or less in conjunction.[1]

This theory, though plausible, is perhaps more complex than it need be; for by trying to establish a connection between the solar spots and the zodiacal light, it aims at too much. On the other hand, it is defective in so far as it fails to account for the relation between the periodicity of the spots, and that of the disturbance of terrestrial magnetism and the frequency of the aurora borealis. It is also objectionable on the ground of the very near approach to the Sun which the planetary bodies are supposed to make during their perihelion passage, in order to their raising a tidal wave by the action of their gravity alone. This last objection is of a two-fold character; for so near an approach would, in the first place, enhance the risk that the bodies might experience resistance from becoming entangled in the solar envelopes, and so losing a portion of their progressive motion—consequently of their periodic time. In the second place it would occasion a perihelion passage so rapid as to produce a very dif-

[1] See *Quarterly Journal of Science,* April 1864.

ferent sort of motion in the spots from what is actually observed.

To understand this last objection, it must be borne in mind that, if it be of the nature of a tidal wave caused by planetary bodies revolving round the Sun, the spot must to a certain extent follow those bodies in their revolution, much as the terrestrial tides follow the motions of the moon. Indeed the view that the spots are due to tidal action, greatly affects the evidence furnished by their motion in support of the inferred rotation of the Sun on its axis. For here three possibilities arise. 1st. The Sun may have no rotation on his axis at all, and the motion of the spots may be entirely due to that of the planetary bodies raising the tidal wave which would follow them in their course. 2nd. The Sun may rotate on his axis in the same direction as the planetary bodies revolve, and the observed motion of the spots may be owing partly to the rotation and partly to the revolution. Or 3rd. The Sun may rotate on his axis in a direction contrary to that in which the bodies revolve; so that the rate of motion of the spots may be the resultant of these two counteracting impulses.

Suppose that the revolving bodies which cause the spots were to approach, during their perihelion passage, to within 700,000 miles of the Sun's centre, so bringing them to about the same distance from his surface that the moon is from the Earth. Suppose further that they begin to exert their sensible action in raising a tidal wave on approaching within a million of miles of the Sun's centre. Their rates of motion at these points in their course would be the same as those of bodies revolving at these respective mean distances from the Sun; consequently so rapid as to be incompatible with the slow motion of the spots, and in a more especial manner with the reappearance of the same spot on opposite sides of

the Sun's limb, at several successive intervals of between twelve and thirteen days.[1]

The foregoing considerations indicate that Sir John Herschel's hypothesis needs to undergo considerable modification.

In a series of papers submitted to the Royal Society, Messrs. De la Rue, Balfour Stewart and Loewy have traced a remarkable relation between the spots and certain configurations of the planets, chiefly of Jupiter and Venus. The subject has been more recently investigated by Professor Daniel Kirkwood, whose researches are published in the 'Proceedings of the American Philosophical Society.' He shows the periodicity of the spots to be incapable of explanation by attributing them to a tidal action of the planets, save on the assumption of there being a particular part of the solar surface more susceptible than the rest to this tidal influence. But he points out how, if this assumption be made, a tidal action of the planets would explain the periodicity of the spots, that of Mercury at his perihelion being most influential. It then exceeds that of any of the other planets, even Jupiter and Venus, each of which exerts a mean influence more than double that of our globe. While the mere periodicity of the spots, however, is well explained by this assumption, there remain three other phenomena for which it fails to account. These are the remarkable conformation of the spots, their rapid changes of appearance, and their connection with terrestrial magnetism and the aurora borealis. It is, therefore, needful to look for some different, or at least additional efficient cause.

Assuming the general principle that the spots are of the nature of a tidal wave, raised by small planetary bodies moving round the Sun, it seems needful, in order

[1] See note B.

to explain the connection between the spots and the variations in the Earth's magnetism, to suppose these planetary bodies to be composed to a great extent of magnetic iron. This supposition would have a double advantage. It would not only explain the periodic changes in the Earth's magnetic condition, but it would add another force to that of gravity, to help us in accounting for the formation of the spots. In their relation to magnetism, bodies are distinguished into two sorts—paramagnetic and diamagnetic. The former are attracted by both poles of a permanent magnet; the latter are repelled by both poles. Hence a paramagnetic body places itself in a line joining the two poles of the magnet; while a diamagnetic body places itself in a position across that line. Even gases and vapours partake of these qualities—oxygen gas in particular being strongly attracted by the magnet.

Now suppose that, between the bright luminous region of the photosphere and the true surface of the Sun, there exists, as indicated by the phenomena of the spots, a vast thickness of non-luminous gases or vapours, which form the nucleus and umbra of the spot, and that these are paramagnetic like oxygen; that gas itself being probably a large ingredient in the stratum. Suppose further that the gaseous medium, in which the luminous bodies of the photosphere float, is also paramagnetic, but non-luminous and quite transparent, while the luminous bodies themselves, which shine in the photosphere, whatever be their nature otherwise, are diamagnetic. Granting, moreover, that there may be planetary bodies, composed chiefly of magnetic iron, revolving round the Sun at a moderate distance from his surface, it would happen that these would, at stated periods, act in conjunction, and so produce effects which none of them singly could manifest. They would not only tend by their mere

gravity to raise a tidal wave, but the magnetism, acting on the paramagnetic gases and vapours, would draw them upwards, while the diamagnetic luminous bodies would be scattered laterally away from the centre of action.

Magnetic meteors would, moreover, be greatly more effective while acting in conjunction, than non-magnetic bodies exerting only the attraction of gravity. For the attraction or repulsion produced by a magnetic body increases as the square of the magnetic power. Two equal magnetic meteors acting in conjunction would therefore exert on a paramagnetic body four times the attraction, and on a diamagnetic body four times the repulsion, that either of those meteors would exert if acting singly.

Thus the peculiar phenomena attending the formation of a spot, would be produced more certainly than by the action of gravity alone. The same conjunction, which would thus develop a spot in the Sun, would manifest itself by an increased disturbance of the magnetic needle on the surface of the Earth.

The electrical tension at the surface of the Sun, the existence of which is indicated by the repulsive action exerted on comets during their perihelion passage, strongly tends to favour this explanation of the origin of the spots. For the relation between magnetism and electricity is so intimate, that the one cannot be in a state of activity without the other. Indeed the electrical tension at the surface of the Sun might explain the magnetic condition of the iron, of which the small planetary bodies are assumed to be in great measure composed.

The view, that magnetic and electrical action is concerned in the production of the solar spots, is greatly favoured by the radial arrangement which the luminous material assumes in the penumbra, the direction of this radiation being all towards the nucleus. Such radial

arrangements are characteristic of magnetical action. The idea that the disturbing bodies which produce the spots consist mostly of magnetic iron, is, moreover, the only plausible mode of accounting for the connection between the spots and the terrestrial phenomena of the magnetic variation and the aurora borealis.

The introduction of magnetic and electrical action to explain the formation of the solar spots, moreover, allows us to suppose the disturbing bodies to be placed at a more considerable distance from the Sun than does the hypothesis of their acting by mere gravity alone. Indeed it renders it necessary to assume their perihelion distance to be not so small as to cause their temperature to be raised to a pitch too high to be compatible with their continuing in a magnetic condition.

M. Leverrier, from calculations based on certain disturbances affecting the planets Mercury and Venus, has shown it to be probable that there exist two rings of minute planetary bodies—one between the Sun and Mercury, the united mass of whose component bodies is a little less than the mass of that planet; the other between Venus and the Earth, the united mass of whose component bodies is about a tenth of that of our globe. If this view be correct, the probability would be that it is only, or at least chiefly, the innermost of those two rings which is effective in producing the spots. The periodic times of the bodies composing such a ring would be less than that of the planet Mercury, which is only eighty-eight days.

In order, therefore, to account for the period of about eleven years, which regulates the recurrence of the minimum of the solar spots, it would be needful to suppose that the bodies composing the ring are incapable of producing a spot when they act singly, and that it requires the conjunction of several to raise a perceptible tidal

wave. That such is the fact is rendered probable by the appearance of the spots. Were the wave raised by a single body, it would be dome-shaped, and the spot would be either circular or elliptical, according as it might be affected by the rotation of the solar atmosphere. But the spots are exceedingly irregular in their form, presenting an appearance exactly such as would result from the conjoined action of several bodies placed near each other. The mode in which a spot breaks up, moreover—one portion of it going in advance and another trailing behind, so as to produce lines of little spots lying in a direction nearly parallel to that of their progression, also confirms this view. The greater frequency of spots at the season when the planet Venus and our own globe are nearest the Sun, further indicates that these two bodies lend their aid to the smaller disturbing masses in raising the tidal waves. Now if the spots be thus produced, not by single bodies, but only by conjunctions of several, their periodic reappearances will be regulated—not by the individual periodic times of those bodies, but by the periods of the recurrence of their effective conjunctions. The eleven-year period of least spotting, then, will be best explained by supposing the arrangement of the masses to be such, that their effective conjunctions are reduced to a minimum nine times in a century, and increased to a maximum the same number of times; but that every fifty-six years the number of those conjunctions occurring within a given time attains its greatest amount.

This view is further confirmed by the reappearance of the same spot several times in succession, on the surface of the Sun. For this indicates that the bodies continue to act in conjunction for a considerable period, as must be the case with the masses composing a ring, which, differing very little in their mean distances from the Sun, must likewise differ very little in their periodic times.

If the periodicity of the maxima and minima of the spots be thus due to the recurrence of certain conjunctions of the disturbing bodies, and not directly to the periodic times of the individual bodies themselves, then these last may be greatly reduced, and it becomes allowable to suppose the disturbing bodies to be those composing the ring within the orbit of Mercury, to which M. Leverrier attributes certain irregularities observed in the motions of that planet. In this case their periodic times will be less than eighty-eight days; and there is thus raised a probability that they may closely approximate to the periodic times of the spots themselves. For, if the spots be tidal waves raised by bodies moving within the orbit of Mercury, these waves must follow the movements of the disturbing bodies, and to a certain extent exhibit the same rate of motion.

At this point the disposition of the faculæ becomes available as a link in the chain of evidence. It has been stated that the faculæ are for the most part accumulated at the rearward of the spot, but that in some few instances they are gathered in front of it, and in other cases both in front and rear. Now this variation in the arrangement of the faculæ has most probably some dependence on the relation of the periodic times of the disturbing bodies to the period of the Sun's rotation on his axis.

The phenomenon may be imitated, and the point in question illustrated, in a simple way. Let a long narrow trough blackened inside be filled with water, and let some fine white powder be strewn upon it, so as to cover the entire surface. Let several small discs of blackened cork be made, and let a piece of iron wire be passed through each. Let the weight be so adjusted that the cork may be nearly of the same specific gravity as the water, but so that it may not show itself above the white

powder. Let a gentle current be established in the water, by drawing it off slowly at one end of the trough. Now let a pretty strong magnet be held over the spot where the corks have been placed. These will immediately rise to the surface and show themselves above the white powder. If the magnet be kept still, or moved very slowly in the direction of the current, but not so fast as the current is flowing, the white powder will collect in rear of the corks. But if the magnet, trailing the corks along with it, be moved faster than the current, the white powder will accumulate in their front; while if the magnet be moved at precisely the same rate as the current is flowing, the powder will collect indifferently in front and rear of the corks.

Here the white powder represents the luminous material of the solar photosphere, the magnet the disturbing body, the blackened corks the non-luminous gases raised into a tidal wave by its action, the current corresponds to the rotation of the Sun, and the collection of the white powder to the faculæ. It will thus be seen that the disposition of the faculæ indicates the relation which the motion of the disturbing bodies bears to that of the Sun's rotation. When these bodies move slower than the rate of the Sun's rotation, the faculæ accumulate in the rear of the spot; and this happens in the majority of cases. When the disturbing bodies move faster than the Sun rotates, they drive the luminous matter before them, so that the faculæ accumulate in front of the spot; and this they do in a few instances. When the faculæ gather both in front and rear of the spot, which they do in a greater number of instances, it is an indication that the movement of the disturbing bodies is almost exactly at the same rate with that of the Sun's rotation.

If these views be correct, they will help to indicate

the position of the ring of disturbing bodies to within narrow limits of error. For the shortest observed period of revolution of a solar spot is 24·97 days, and the longest 28·36 days, while, according to the above hypothesis, the period of the Sun's rotation lies somewhere between these two points, but nearer the former than the latter. The shorter of these two periods would make the mean distance of the disturbing bodies 15,263,000 miles; the longer 16,615,000 miles from the centre of the Sun. The ring would thus be placed nearly midway between the Sun and the planet Mercury—a very likely position for it to hold. The thickness of the ring, measured in the direction of a line drawn from its circumference to the Sun, would be about 1,352,000 miles, and its extreme breadth 100° of the periphery of the greatest orbit, or about 28,998,000 miles. Within such extended limits of space, there is ample room for a vast number of small bodies to revolve round the Sun, to form numerous conjunctions in the course of their revolutions, and during the subsistence of those conjunctions to exert a tidal action on the solar photosphere. Some of these bodies may differ in their periodic times by only a few hours; so that, on coming into proximity, they might continue near each other, and exert their joint action during several revolutions, so accounting for the reappearance of the same spot during two or three rotations of the Sun on his axis. Supposing the rotation of the Sun to be a little faster than the revolution of the disturbing bodies, in such a case, the position of the spot would, at each reappearance, be somewhat to the rearward of the place it would occupy did its motion depend on the rotation alone, or were the rates of rotation and revolution the same. This consideration will satisfactorily explain the remarkable case, noticed by Professor Fearnley, of a spot which appeared on the Sun's disc three successive times,

and whose periods of revolution seemed to be slower as calculated from each reappearance.

Nor is there in this theory anything to prevent our supposing that the larger planets aid these magnetic meteors in producing the spots, and contribute to account for their periodicity. It renders unnecessary Dr. Kirkwood's assumption of there being a particular part of the solar disc more liable to spot-formation than the rest: because the reciprocal aid furnished to each other by the planets and the meteors, in their action on the solar surface, would, without the help of that assumption, account for the connection between the spot-periods and the position of the planets—more especially that of Mercury at its perihelion. For if there be at that time a conjunction of meteors favorable to spot formation, the action of Mercury will tend greatly to increase it; whereas if at the time of Mercury's perihelion there be no favorable conjunction of the meteors, there will be no extraordinary development of spots. The same remarks apply to the action of the other planets.

When drawn upwards by the magnetic attractions of the disturbing bodies, the non-luminous bodies will ascend with a whirling motion, such as characterizes the ascent of smoke or steam. For this species of motion is assumed to a greater or less extent by all large masses of elastic fluid, when in a state of transference from one point of space to another. Mr. Dawes has frequently observed this whirling motion in the umbra of spots.

According to this theory, there will be, between the umbra and penumbra of a spot, no physical difference of level. The non-luminous gases will merely rise to the level usually occupied by the luminous bodies and displace them. The difference of level will be only apparent. The uppermost portion of the umbra will be occupied by the non-luminous gaseous medium, in which the luminous

bodies of the photosphere usually float, and from which they are for the time driven away. As this gaseous medium must be quite transparent, it becomes obvious why the umbra of a spot is never traced to the very edge of the disc, there being always a narrow luminous thread traced beyond it on the limb. This thread is a portion of the photosphere seen edgewise through the transparent non-luminous gaseous medium of the envelope—a circumstance proving the photosphere to have a considerable thickness. There must, however, be a physical difference of level, as regards the luminous bodies occupying the penumbral region of the spot, those diffused over the general surface of the photosphere, and those accumulated in the faculæ. For in the penumbra the luminous material is as it were scraped off, and heaped up in the faculæ. Hence it becomes possible for the faculæ to project slightly beyond the circular edge of the Sun, as they have on rare occasions been seen to do. Such a projection, however, indicates a great amount of real height; for to protrude visibly at all, a facula must rise at least 400 miles above the general surface of the photosphere.[1] From this estimate some notion may be formed of the average thickness of the photosphere itself. The fine thread of light always observed to separate a spot from the Sun's circular outline, and which probably corresponds to the thickness of the photosphere, indicates that it also cannot be estimated at less than 400 miles.

The foregoing hypothesis, then, furnishes a satisfactory explanation of nearly all the phenomena. It accounts for the connection between the solar spots and terrestrial magnetism, with its related phenomenon the aurora borealis. It also explains the radiated appearance of the penumbra, and the peculiar disposition of the faculæ in reference to the spot. It accounts for the maxima

[1] See note C.

and minima of the spots, and shows why the rotation of the Sun appears faster when estimated from one set of spots than it does when estimated from another, and how it is that the same spot may reappear two or three times in succession on the solar disc. It explains the restriction of the spots within certain limits of latitude on either side of the Sun's equator, why they are more abundant on the northern than on the southern side, and why they make their appearances in all longitudes within those limits. It accounts for the irregular aspect of the spots, and their tendency to trail into long tracts nearly in the direction of their own revolution. It shows why the spots are of more frequent occurrence when the Earth and Venus are nearest the Sun. It may also explain why some spots are less perfectly developed than others. For such shallow spots may be caused by conjunctions of those disturbing bodies which are most remote from the Sun, or which contain the smallest proportion of magnetic iron. On the same principle may be explained the appearance of faculæ when there is no spot—the disturbing bodies in this case only ruffling, as it were, the surface of the photosphere, so causing a displacement of the luminous masses of which it is composed.

There is indeed but one phenomenon left unexplained, namely, the lateral movement of some of the spots, observed by Mr. Carrington. But this motion may be caused by the greater or less obliquity of the orbits of the disturbing bodies in reference to the direction of the Sun's rotation on his axis; or it may be due to local causes having their origin in the solar atmosphere itself, connected with changes in its temperature or electrical condition.

It may be objected to this mode of accounting for the solar spots, that the disturbing bodies, which raise the tidal waves, ought sometimes to be themselves visible as

dark spots on the face of the Sun. But it is by no means certain that they are not thus visible. Some of the minute dark spots termed pores, may be the shadows cast by these bodies; for their shadows may be so small as to be easily confounded with the pores. Moreover the transit of the shadow of any individual planetoid across the disc of the Sun would last so short a time, as to add to the difficulty of detection arising from the smallness of the shadow itself.

But this theory, it will be perceived, is in accordance nly with the idea, that the solar spots are openings in the photosphere, due to a tidal upheaving of the transparent non-luminous gaseous medium, in which the luminous bodies of the photosphere float, as also of the non-luminous gases or vapours underlying this medium. It is altogether inconsistent with the notion that the spots are of the nature of dark clouds, floating on the bright surface of a solid or liquid incandescent mass. Indeed the formation of such clouds would be inexplicable. Neither would it be possible on such a supposition to account for the periodicity of the spots, for their restriction to certain limits of latitude, for their connection with terrestrial magnetism, for the radiated appearance of the penumbra, for the disposition of the faculæ, or indeed for almost any of the complex phenomena which the spots present. When it is considered how various and complex these phenomena are, a hypothesis which explains the whole of them may lay fair claims to acceptance, as being a close approximation to the truth; while a hypothesis which leaves them all unexplained ought to be rejected.

CHAPTER VIII.

SOLAR RADIATION.

Before investigating further the nature and source of solar light and heat, it is needful to make some research respecting solar radiation generally, and to have before the mind some definite conceptions in regard to the characteristics which distinguish heat from light.

In the solar spectrum there can be detected three powers—first, a power to render bodies hot; second, a power to excite the optic nerve, so producing vision; and, third, a power to promote chemical action. Now all these three powers are exerted by vibrations existing in a rare elastic medium termed the ether, infinitely extended and penetrating the pores of all bodies. These vibrations are transmitted to the earth from the sun, where they are excited by forces adequate to their production, but of whose precise nature we are ignorant. While in the course of their transmission through the ether, the vibrations are said to be radiant, and they constitute the solar radiation.

The various effects produced by these movements in the ether, are due to very simple differences among the vibrations themselves—chiefly to their greater or less rapidity. The slowest vibrations are those which render bodies hot. This they do by exciting corresponding vibrations in the constituent molecules of the bodies themselves; and it is in this vibratory motion of its particles that the temperature of a body consists. The most

rapid vibrations are those which promote chemical action. This they accomplish by exciting corresponding rapid vibrations in the ultimates of simple bodies, and also in the elemental ultimates constituting the molecules of compound bodies. By these vibrations in the case of mixtures of simple bodies, the ultimates are thrown at intervals into greater mutual proximity, and their combination is thus promoted; while in compound bodies the ultimates constituting each molecule are at intervals separated, the chemical attraction holding them together thus becomes weakened, and decomposition is favoured. These very rapid vibrations are called actinic, and their effect is termed actinism. It is by vibrations of an intermediate degree of rapidity that the optic nerve is excited. In the case of the human eye, the vibrations thus capable of producing vision have a limited range of rapidity—the quickest visible vibration having just twice the rapidity of the slowest, so corresponding to a musical octave. With the eyes of other creatures the range may be greater or less.

It will thus be perceived that it is only those vibrations of intermediate rapidity that constitute what we term light. The name light is therefore not that of a substance, but merely of a species of vibratory motion, and is similar in import to the name sound, which is that of another species of vibratory motion existing in the air, and which affects our nerves of hearing. In like manner the slower solar vibrations, so long as they are confined to the ether, are not what we term heat. They are merely capable of exciting corresponding vibrations in ponderable bodies, whose vibratory condition thus excited is called heat. So also the very rapid vibrations have no chemical qualities in the ordinary sense of that term. They do not act on the elements by any species of chemical attraction or elective affinity. They merely

excite vibrations of a rapidity corresponding to their own in the ultimates of simple bodies, and in the ultimates composing the molecules of compound substances—these ultimates being predisposed to take up such very rapid rates of vibration; but this is evidently a mechanical, not a chemical action. Actinism is therefore not to be confounded with the chemical action which it merely promotes.

It is a point not yet determined, whether vision is produced simply by a vibratory condition of the nervous fibres, induced by the vibrations of certain degrees of rapidity communicated to them by the ether, or whether the nervous substance is thrown into a state of actinism resulting in chemical change. In the latter case, there would be no real physical distinction between the luminous and actinic vibrations as regards their modes of action. The difference would be only in the mode in which our perceptions are excited; it would be physiological as distinguished from physical. There is no doubt as to the existence of vibrations in the optic nerve, excited by those in the ether, and corresponding with them in rate. The questions are whether or not these vibrations result in chemical change, and whether our perception is caused simply by the vibrations or by the chemical change, if any, which is their result.

The vibrations exciting vision are the only sources whence we can obtain any notion of the actual degree of rapidity, with which these motions in the ether are performed. The clearest idea that can be gained is acquired by conceiving of the ether as composed of ultimates which are mutually repellant, separated by minute spaces larger than themselves, each ultimate retaining a fixed position, in which it is held by the balance of the forces exerted upon it on all sides. When an extraneous force acts on such an ultimate it is disturbed from its point of rest, it

performs a small gyration round that point, and then returns to it. But each ultimate thus moved disturbs all its neighbours, causing them to perform an exactly similar movement. Tracing this motion, as it is propagated from ultimate to ultimate in any given direction, it is found that, at certain intervals of distance, there are always two ultimates in precisely the same phase of their motion—that is, in exactly the same position relative to their point of rest, at the same instant of time. Between these two ultimates, in the same line of direction, are others in every possible phase of their motion. The distance between the two ultimates which are in the same phase is termed a wave or undulation: so that the length of a wave is the distance which the motion travels from ultimate to ultimate in a right line, while each ultimate is performing a single revolution in its orbit. If, therefore, we can measure the length of the wave, and also the time the motion takes to travel that distance, we can also ascertain the time occupied by each individual ultimate composing the wave in performing its proper motion.

Now certain optical phenomena render it possible to measure the length of the wave with considerable exactness, and also the time in which the motion travels that distance. The length of the longest luminous wave is about 30, and of the shortest, about 15 millionths of an inch. The speed with which the motion travels, is, according to the most recent determinations, about 185,000 miles in a second. Travelling at this rate, light will traverse the longer of these minute wave-lengths in about the 400th, and the shorter in about the 800th part of the billionth of a second. Such, then, are the durations of a single vibration of each ultimate involved in these wave lengths. Or supposing the vibrations to be continuous, there would be about 400 billions of them in the one case, and 800 billions of them in the other, performed

in a second of time. As respects the invisible portions of the spectrum, in that extending beyond the red, the longest wave may probably correspond to vibrations performed at the rate of 200 billions in a second; while in the region extending beyond the violet, the shortest wave may probably correspond to vibrations performed at the rate of 1,600 billions in a second.

The extreme velocity with which the wave motion travels in the case of light, when contrasted with its rate of progress through the air in the case of sound, the former being upwards of a million times greater than the latter, indicates an enormous disproportion between the two forces which are brought into play. In the case of sound, the force by which the particles of air are retained in their places, or restored to them when disturbed, is probably that of gravity. If so, the force retaining any particle of the ether in its place, or restoring it when disturbed, must be upwards of a billion times greater than terrestrial gravitation. The amazing rapidity of the luminous vibration further indicates, that the distance to which any disturbed ultimate is moved from its point of rest, and through which it is dragged back by this enormous force, must be extremely small. If the wave-length be divided into 100,000 million parts, one of such parts would be about from three to six times greater than the distance to which a disturbed ultimate departs from its point of rest in the case of the ether. It may hence be inferred how inconceivably minute must be the ultimates themselves, and how great a number of them may be comprehended in the length of a wave.[1]

The fact that the force, by which the ethereal ultimates, when set vibrating, are restored to rest, so immeasurably exceeds the force of terrestrial gravitation, indicates that

[1] See note D.

the circumstance of the sun's having at his surface a gravitating power upwards of twenty-eight times that of the earth can produce no appreciable effect on the ethereal vibrations. These will be excited at the surface of the sun, with hardly any greater difficulty than they are at the surface of the earth.

In the foregoing estimates it has been assumed that the disturbing force, as well as the recoiling force, is constant. But the disturbing force may vary indefinitely, and so cause great variations in the extent of the excursion of each ultimate from its point of rest, and the amplitude of the resulting vibration, giving rise to different degrees of loudness in the case of sound, and of brightness in the case of light. Such variations will, of course, affect the proportion which the excursion bears to the wave-length. In the ether, however, these excursions must be limited by the extreme intensity of the force by which the ultimates are retained in their places.

The comparative extent of the excursion of each particle is measured by the intensity of the effect produced, which is proportional to the square of the amplitude of the vibration. Thus twice the amplitude will produce four times the intensity, three times the amplitude nine times the intensity, and so on. The amplitude of the vibration must accordingly be estimated as it exists at the recipient surface, where the effect whose intensity is measured may be produced, the effect being either heat, or brightness, or actinism. Now the amplitude of the vibration at the recipient surface may be affected by three distinct causes. First, it may depend on the number of lines of wave propagation, or rays, brought to bear on one and the same point of the surface. This produces the adventitious intensity, so called because it is independent of the nature of the source of the radiation, or of the character of the radiation itself. This adventitious intensity varies

inversely as the square of the distance from the source; at twice the distance the intensity is one fourth, at three times the distance it is one ninth, and so on. Secondly, the amplitude of the vibrations at the recipient surface may depend on their amplitude as they start from their source. Thirdly, the effect at the recipient surface may depend on the number of impulses propagated along one and the same line of direction in a given time. The intensity of effect arising from either the second or the third of these causes is termed intrinsic intensity; because it depends directly on the quality of the radiation, and is quite independent of the distance between the source and the recipient surface.

The third cause is doubtless the more operative in producing intrinsic intensity. There are no means of ascertaining with precision how long the vibratory condition of the ether may be continued from a single impulse communicated to it, but judging from the instantaneousness of the electric spark, it must be extremely short. It has been ascertained, however, that impulses renewed at the rate of ten in a second suffice to maintain continuous vision, and to make the radiation appear constant. Now when it is remembered that in the tenth of a second there may be performed from nearly 40 to 80 billions of vibrations capable of affecting the optic nerve, it will be perceived that there is vast room for an accumulation of effect. The waves in the ether, which travel along any single line of propagation, and ultimately reach the eye, there producing a perception of continuous brightness, may arrive at intervals of only a tenth of a second, and so be separated from each other by spaces of 18,500 miles. And this explains how it is that these lines of propagation, or rays, may cross each other in all directions, without confusing the effects of the impulses. But if, instead of arriving at the rate of 10 in a second,

they come at the rate of 100 or 1000 in a second, they will obviously produce a much more intense effect on the optic nerve. They will there excite vibrations of greater amplitude, and so give the perception of enhanced brightness.

It may thus happen that a light, whose adventitious brightness is, by reason of the distance of the source, and the consequent small number of lines of propagation which enter the eye, extremely feeble, may yet have a great amount of intrinsic brightness, by reason of the large number of impulses travelling along each line of propagation in a given time. Hence it is that the fixed stars, notwithstanding the very small number of rays proceeding from them which can be introduced into the eye, are yet able to excite vision, in consequence of the rapidity with which the impulses succeed each other along those lines of propagation; and for the same reason they are capable of impressing their images on photographic plates.

The strength of the impulse, by which a vibratory motion is produced, is measured by both the rapidity and amplitude of the resulting vibration. The greater the excursion of the disturbed ultimate from its point of rest, and the shorter the time in which that excursion is performed, the greater is the disturbing force. But for any given amount of force, the smaller the amplitude the greater will be the rapidity, and *vice versâ*. Hence these two, amplitude and rapidity, are mutually convertible. By lessening the amplitude the rapidity may be quickened, and by lowering the rapidity the amplitude may be increased. Halving the amplitude quadruples the rapidity.

There is a class of substances, among which fluor-spar is conspicuous, which have the power of thus lowering the rate of the ethereal vibrations, a property which has been hence termed fluorescence. Disulphate of quinine is among the most energetic of fluorescent bodies. When

the invisible rays beyond the violet are allowed to fall on this substance, it begins to glow with a beautiful blue light. Uranium glass, under the like circumstances, glows with a green light. In these cases the very rapid vibrations of the ether communicate their motion to the molecules of the fluorescent substance, or perhaps only to the constituent ultimates of those molecules, and establish in them vibrations which are of longer period than are those by which they are excited. These in their turn establish in the ether a new set of vibrations which are of their own longer period. This secondary set of ethereal vibrations are thus reduced to that slower rate of rapidity which renders them capable of affecting the optic nerve.

Similar phenomena are presented at the other end of the spectrum, but in an opposite direction. From the flame of hydrogen gas the vibrations propagated are for the most part so slow that they have little power of exciting vision. The vibrations, however, are of large amplitude, and exert a great heating power. Now if platinum wire be introduced into the flame, it will instantly glow with a vivid white light. The vibrations have been transferred from the watery vapour formed by the hydrogen flame to the platinum. In that dense metal their amplitude is much diminished, but their rapidity is in a corresponding degree increased, and they thus become capable of powerfully exciting the optic nerve. But if the luminous vibrations from the platinum wire be received on a surface coated with lamp-black, their luminosity will be destroyed, and they will excite mere heat. The vibrations are transferred to the lamp-black, their amplitude is increased, but their rapidity is lowered to such a pitch that they cease to excite vision. The convertibility of mere heating into luminous vibrations has been recently exhibited in a still more striking

manner by Professor Tyndall. By collecting the invisible rays lying beyond the red extremity of the spectrum into a focus, and receiving them on a blackened surface of platinum he has rendered the metal incandescent.

The luminous waves may be apparently lengthened or shortened by another cause. If the source of light be either approaching the eye or receding from it, with a speed bearing some appreciable proportion to that of light, the wave-lengths will, in the case of an approach, appear to be shortened, and the spectrum will be shifted towards the violet end; while in the opposite case the wave-lengths will appear to be lengthened, and the spectrum will be shifted towards the red end. So also with sounds. On rapidly approaching a sounding body its tone will appear sharpened, on retiring from it the tone will appear flattened. The wave is shortened in the one case and lengthened in the other, by the space which the moving body travels during the undulation.[1]

The adaptation of the optic nerve to receive impressions from vibrations of a certain rapidity is remarkable. The invisible rays beyond the red, when in sufficient quantity to impart to the hand an almost insupportable degree of heat, may yet be received into the pupil of the eye without exciting any sensation whatever. This has been proved experimentally by Professor Tyndall. On the other hand, provided the vibrations be of the proper degree of rapidity, their amplitude may be so small as to be totally inappreciable by any other means than by the optic nerve itself. A candle is visible at the distance of about a mile; but the vibrations propagated from it to that distance could not produce the smallest effect on the most delicate thermal pile, nor on the most sensitive

[1] From observations made with the spectroscope on the star Sirius, Mr. Huggins has found its spectrum to be sensibly shifted towards the red end, whence he infers a rapid retreat of that star from the earth, or *vice versâ*.

photographic plate. Again, a light almost insupportably bright to the eye might, by being passed through certain media, be quite deprived of its power to affect either a sensitive photographic plate or the thermal pile. In like manner, the actinic undulations lying beyond the violet end of the spectrum, while they exert no influence either on the thermal pile or on the optic nerve, may nevertheless be gathered into an invisible focus and produce a photographic image. The substances most sensitive to their action are the salts of silver and the double salts of chromic acid, both of which undergo decomposition, or at least modification, under their influence. Although the result is chemical, the action itself is purely mechanical; arising from the vibratory motion communicated to the ultimates composing the salts. Nevertheless the explanation of this phenomenon is rendered easier, by assuming the ether itself to be composed of two fluids mechanically alike, but chemically different, that is, having different relations to the chemical elements.

To illustrate this point, let it be assumed that the ether does consist of two such elastic fluids intimately mingled, and suppose one of them to be less repellent towards chlorine than it is towards silver; the other less repellent towards silver than it is towards chlorine. Then in the pores of the chloride of silver, the first of these fluids will accumulate near the chlorine element of each molecule of the salt, and the second near its silver element; while in the intervening spaces the two fluids will remain intermingled. When the very rapid actinic vibrations agitate the ether existing in the pores of this salt, a part of their energy will be communicated to the ultimates of chlorine and silver respectively, and they will vibrate at the same rapid rate. In performing these vibrations, the ultimates of chlorine and silver will alternately approach and recede—a movement which will

promote the intermingling of the ethereal fluids existing between them, and result in rendering their intermixture complete. While they continued partially separated, their separation would promote the attraction of the chlorine ultimate for that of the silver; because each of these would have next to it that species of ethereal fluid towards which it is least repellent. But the readmixture of the two fluids, resulting from the vibratory motion, will terminate this state of matters, and both the chlorine and the silver ultimates will be subjected to the full repulsive energy of the intermingled fluids. The result will be a tendency of the chlorine to separate from the silver, and disengagement will ultimately ensue. The advantage of this assumption of two ethereal fluids becomes more apparent, when it is applied in aid of the explanation of the latent photographic image, which requires a developer to bring it into view.[1]

Recent researches by Professors Tyndall, Maxwell, and Sir William Thomson, moreover, show that the dual character of the force exhibited by paramagnetic and diamagnetic bodies, united to the fact that this force can be induced at a distance—the energy passing through the free ether—is strongly corroborative of the view that the ether consists of two fluids, which the chemical elements have the power of separating from each other. In the pores of bodies accordingly these two fluids are supposed to exist in alternate strata of extreme thinness; this stratification being the more decided the more paramagnetic or diamagnetic the body may be; while the planes of stratification coincide with those of greatest density in the mass.

The relations in which different substances stand to the ethereal vibrations are exceedingly diverse. On this subject much light has been recently thrown by the

[1] See note E.

researches of Professor Tyndall. His experiments tend to show that the relation which any substance bears to the ethereal vibrations is to a great extent inherent, and for the most part independent of the condition in which the body may happen to exist. When the vibrations reach them, some bodies readily take them up from the ether, which is deprived of a corresponding amount of its motive energy. Such bodies are therefore said to absorb the radiation. Others, again, suffer the vibratory motion to pass on without taking up any sensible part of it, and are therefore said to transmit the radiation.

Bodies differ much as regards the character of the vibrations which they absorb or transmit. Some absorb the slow vibrations and transmit the quick. All such bodies become heated by the motive force thus communicated to them, but appear transparent to the eye. To this class belong water and its vapour, solutions of alum, olefiant gas, &c. Others absorb the quick vibrations and transmit the slow. These appear opaque to the eye and acquire but little heat. Such are iodine dissolved in bisulphide of carbon, and hot nitrous acid gas. A third class absorb both the slow and the quick vibrations, and these, while opaque to the eye, acquire a considerable amount of heat from the radiation. Of this sort lamp-black is an example. A fourth set allow both the slow and the quick vibrations to pass through them, without taking up any considerable amount of the motive force. These are transparent and are not appreciably heated by the radiation. Such are the simple permanent gases, oxygen, hydrogen, and nitrogen, dry atmospheric air, and in a less degree rock salt and bisulphide of carbon.

The same substance generally bears the same relation to the radiation when in the liquid and when in the vaporous condition. Thus water and watery vapour alike absorb greedily the slow vibrations, but transmit the

quick. Bisulphide of carbon and its vapour allow both sets to pass through with nearly equal degrees of facility.[1]

The ease with which a body absorbs any given set of vibrations depends chiefly on the degree in which the rate of vibration, as it exists in the ether, approximates to the rate of vibration which the molecules or ultimates of the absorbent body tend to assume. If the rate be the same, the facility will be greatest; whereas if the rate be either much slower or much quicker, the molecules take up the motion with difficulty, and rather suffer it to pass on through the ether existing in the intervals between them. The state of aggregation of the molecules sometimes greatly affects their capability of taking up the vibrations. In lamp-black for instance, this capability is great; but in diamond, which is the same substance in a different state of aggregation, the vibrations are freely transmitted, and the absorption is correspondingly small.

When a body, which absorbs the radiation, has its molecules thereby set a vibrating at the rate peculiar to themselves, these molecular vibrations in their turn produce corresponding vibrations in the ether of the same rate. They are then said to radiate or propagate the motion. This secondary radiation proves in some cases a source of deception; because the motion, thus propagated afresh by the molecular vibrations, is apt to be confounded with the primary ethereal vibrations passing freely through the ether existing in the interstices between the molecules. The most powerful absorbents are also the most powerful radiators; for all the motion which they take up from the ether they ultimately render back to it after more or less of delay. Such a powerful absorbent as lamp-black, for instance, is pre-eminent as a radiator: and from this circumstance it appears to transmit a portion

[1] See note F.

of the slower vibrations which it receives. They are not, however, really transmitted in their original state. They are first taken up by the carbon, and then by it as a radiant given out again to the ether. They are, however, lowered in their rate. The vibrations capable of exciting the eye are by the carbon converted into slower vibrations no longer capable of producing vision, but able to develop an appreciable amount of heat. It thus appears as if these slower vibrations had passed through the carbon.

Another important consequence results from this relation between absorption and radiation. It has been stated that bodies absorb with different degrees of facility the radiation from different sources, according as the vibrations propagated by the radiator approximate more or less to the rate at which the molecules of the absorbent body tend to vibrate. Hence it follows that the facility of absorption is greatest of all when the same substance is both radiant and absorbent; because then the rate of vibration is identical in both. Thus lamp-black absorbs most readily the radiation from carbon; while aqueous vapour absorbs most greedily the vibrations propagated from the surface of water; and so of other substances.

The most important case is that of water and its vapour, for it is by its relation to the vibrations transmitted from the sun, that the temperature of our globe is regulated, and its constancy maintained. The absorbent power of our atmosphere is almost entirely due to the aqueous vapour which it contains, and in a less degree to the carbonic acid gas which forms a small proportion of its constituents. According to the estimate of Professor Tyndall, the moisture usually contained in the atmosphere exerts over the slower vibrations propagated from the sun an absorbent power between 60 and 70 times greater than that of the air in which it is contained; while of the

back radiation from the earth 10 per cent. is absorbed by the moisture existing within ten feet of the ground, when the air is of average humidity. The aqueous vapour of the atmosphere will take up still more greedily the back radiation from the surface of the waters which cover so large a portion of the earth's surface. By this beautiful provision, the globe is prevented from losing by radiation more heat than it receives from the sun, and the constancy of its temperature is thus secured.

The proportion of moisture contained in the air greatly affects the difference between the temperatures of sun and shade, night and day. When the air is very moist this difference is small, but when the air is very dry, the difference becomes so extreme as to produce considerable discomfort. On high mountains, when the temperature of the air in the shade is little, if at all, above the freezing point, the heat of the direct rays of the sun may be almost insupportable. The dry air allows the radiation to pass through it without taking up more than a trifling amount of the vibratory motion, and it thus acquires only a slight elevation of temperature; whereas the human frame absorbs the radiation greedily.

These remarks apply only to those slower vibrations which produce heat in bodies capable of absorbing them. But the atmosphere, when dry, exerts a powerful absorptive action on the quicker vibrations which produce vision and actinism. This is proved by the great diminution both of light and actinic effect which takes place towards sunset, when the radiation has to penetrate a great thickness of air, and also by the much greater brightness of the sun's light in summer than in winter. When the atmosphere contains a certain amount of moisture it increases in transparency, and distant objects become more distinct—thus showing that watery vapour, while highly absorbent as regards the slower vibrations,

allows the quicker to pass through it more readily than does dry air. This, however, is only so long as the moisture does not assume the vesicular form, when it becomes mist or cloud. In that case, the luminous vibrations are reflected upwards from the surface of the watery vesicles, and only a small portion of the radiation finds its way through them.

From what has been said, it will be perceived to how great an extent the effects vary, in consequence of differences both in the character of the radiation itself, and in the nature of the substances through which it passes, or on which it falls.

CHAPTER IX.

SOLAR HEAT.

To determine the actual temperature prevailing at the surface of the sun is impossible; because it depends not only on the motive power of the radiation, but also on the capability of the medium occupying the solar surface to assume vibratory motion from the applied force, and of this capability we are ignorant. It may be very small; and in that case the radiation, though exceedingly powerful, may develop little warmth in the medium. It is nevertheless possible, although difficult, to arrive at some definite conclusions respecting the heating power of the solar radiation on its reaching the earth's orbit. The difficult point in the investigation is to ascertain how much the heating power of the radiation is lessened by its passage through the earth's atmosphere.

There are two modes of prosecuting this research. The one is by noting the quantity of ice melted in a given time, when a certain extent of surface is exposed to direct sunshine. The other is by noting the rise in a given time of a mercurial thermometer with a blackened bulb, when suddenly removed from shade to sunshine in air of the same temperature. That the results of these two methods may be compared one with another, it is needful to know the weight of mercury in the thermometer, and the extent of blackened surface which it exposes to the sun's rays. For from the melting of ice may be calculated the corresponding quantity of heat which would be

imparted to one pound of water by a square foot of blackened surface in the first second of time; and the same may be estimated from the rise in a given time of a thermometer of known contents and with blackened bulb, when exposed to sunshine.

Unfortunately the large mass of observations with the black-bulb thermometer have been made with instruments of unknown contents and superficies. They consequently indicate no more than the excess of sun over shade temperature at the time of observation. Nevertheless the results thus obtained are both important and useful. Among the most valuable are those made by Father Secchi at the Roman Observatory, and by Dr. Hooker at different heights in the Himalayan district. The experiments on melting ice, to which the greatest amount of credit is attached, are those of Sir John Herschel and M. Pouillet. From a careful comparison of these observations and experiments, with others made by means of a black-bulb thermometer having weighed contents, it appears probable that, at the outskirts of the earth's atmosphere, the solar radiation, if wholly absorbed, would be capable of imparting to one pound of water, in the first second of time, about 0·1544 parts of a degree of Fahrenheit per square foot of surface, and that it would be able to maintain a black-bulb thermometer at about 125° F. above the point it would mark in the shade, which point, however, would be exceedingly low.[1]

To convey an idea of the power of the solar radiation at the immediate surface of the luminary, it is needful to multiply these effects 46,000 times. Hence for every square foot of the surface of the photosphere about 7,000 pounds of water would be raised 1° F. in the first second of time, were the radiation wholly absorbed; and were it

[1] See Note G.

received on a blackened surface, the heat developed would be 5,750,000 times greater than what would suffice to maintain a black-bulb thermometer at 1° F. above the temperature of the air in which it might be placed. It may not be hence concluded, however, that any such temperature is actually developed at the solar surface; for that would involve the total absorption of the radiation. All that can be fairly inferred is that, were there a substance capable of effecting such entire absorption placed at the solar surface, it would be raised to the above enormous pitch of temperature.

It must be borne in mind that this force, on the supposition of its being generated in the photosphere itself, is half the accumulation of all that is produced in its thickness—the other half being probably directed inwards. From the phenomena attending the approach of a spot to the edge of the sun's disc, it has been inferred that the thickness of the photosphere cannot be less than 400 miles; so that the force propagated outwards is the accumulation of all that is generated in a thickness of 200 miles. Great as the force is, therefore, it involves the generation of only a small amount in each cubic inch, seeing that in a column of 200 miles in thickness, having for its base a square inch of surface, there are twelve millions of cubic inches. The force produced continuously within each cubic inch of such a column would thus be capable of maintaining a constant temperature of less than half a degree Fahrenheit were it wholly absorbed.

This conclusion, however, is consistent only with the supposition, that the force which causes solar light is actually generated in the photosphere itself—a supposition strongly fortified by the phenomena of the willow-leaf-shaped bodies, the faculæ and the spots. Were the light of the photosphere caused by heat emanating from

the body of the sun, the case would be very different indeed. It would then be needful to conclude that the entire mass of the sun is heated to a temperature exceeding 5,750,000° F.; because radiation, generated by heat alone, must be produced by a temperature exceeding in intensity that which it is capable of exciting when wholly absorbed. Now so high a temperature would be inconsistent with the retention of the solid or liquid condition by any substance with which we are acquainted.[1] It does not appear possible, therefore, to suppose the radiation from the sun to be due to the high temperature of its mass, without at the same time concluding the whole of that mass to be in a vaporous condition.

The only escape from this conclusion seems to be the supposition of the radiation's being produced by vibratory motion generated within the photosphere itself; for in that case the mass of the sun, instead of imparting heat to the photosphere, would derive heat from it; and this heat might be so modified by the medium which the radiation has to traverse before reaching the solid surface, that it might there excite only a moderate amount of warmth. For the medium may be so constituted as to reflect a large portion of the radiation outwards, and allow no more to penetrate than what will suffice to produce a beneficial effect.

On the same principle, the possible variations that may subsist in the atmospheres of the different planets, as respects their relation to solar radiation, indicate the manner in which they may be severally adapted to sustain organised beings. Professor Tyndall has shown, not only that the amount and density of the watery vapour contained in any atmosphere may greatly influence its temperature, but also that the admixture of other gases

[1] See Note H.

may produce a like effect. A small quantity of olefiant gas, for example, introduced into an atmosphere, would greatly augment the warmth it would acquire from a given amount of radiation. In some such manner even the remotest planets may acquire, from the vastly diffused solar radiation they receive, an amount of heat sufficient for the maintenance of organic life.

As regards the perception of light and colours, it depends so much on the sensitiveness of the retina and the extent of surface which it presents to the incident radiation, that it is not difficult to imagine how an adaptation of the one to the other may in any instance be secured. Since the nervous sensibility and the extent of exposed surface may be varied indefinitely, the eyes of animals may be suited to every variety in the quantity of solar illumination on the different planets.

The distribution of heat again will depend almost entirely on the nature of the atmospheres which the several planets possess. Nor are we left to mere conjecture in reference to the existence of some such arrangement for equalising their temperature. There is evidence that the planet Mars, though considerably further from the sun than is our globe, has nevertheless quite as genial a clime. It is observed by astronomers that the polar regions of Mars exhibit, at certain periods, a brilliant white and glistening appearance, such as would be produced by the reflection of the sun-beams from snow, and quite distinguishable from the general ruddy aspect of the planet. This appearance is always observed at the pole most averted from the sun, and entirely vanishes when, in its turn, that pole becomes directed towards the central luminary. It attains its maximum at either pole during the winter of the corresponding half of the planet, and wholly disappears in its summer. This circumstance enhances the probability that this white reflection does

really proceed from the polar snows of Mars. Now, these snow-covered regions never extend to more than ten degrees from the poles of the planet, even in the depth of the hemispherical winter; and they totally vanish from that half of the orb which is enjoying the summer's sun. In our globe, on the other hand, the snow-covered regions extend in winter to between thirty and forty degrees from the pole; while even in the warmest summers they are seldom within the limit of ten degrees. It would hence appear, that the arctic regions of our globe, notwithstanding our greater proximity to the sun, are colder than are those of Mars.

The planet Jupiter furnishes similar, though less striking evidence; for his belts are by astronomers attributed to strata of clouds floating in his atmosphere. Such clouds indicate the existence of liquid waters, and these of a temperature sufficiently high to produce extensive evaporation. Hence, although Jupiter be more than five times further from the sun than is our globe, his average warmth does not appear to be inferior to that of the earth; whereas, according to the law of the square of the distance, it ought to be twenty-five times less.

CHAPTER X.

SOLAR LIGHT.

The foregoing discussions have paved the way for investigating with greater advantage the nature of solar light, and the probable source of its supply. Our notions on both these points will be much influenced by the conclusions, which may be reasonably deduced from the evidence, in regard to another question—namely, whether the light is generated in the body of the sun, or in the photosphere itself.

Were the sun an incandescent mass, and its light due to heat alone, its temperature would of necessity be so very high that, as already pointed out, none of its materials would be likely to subsist in any other than a vaporous condition. But in that state the incandescence of bodies becomes exceedingly feeble, as compared with what it is while they continue in the solid or liquid state. The reason is plain. While a substance remains solid or liquid, its ultimates, by reason of their mutual proximity, can vibrate only with comparatively small amplitudes. The motive force, therefore, goes to increase the rapidity of the vibrations, consequently their power to excite vision. But as soon as the restraints imposed by the solid or liquid condition are cast off, and the ultimates have freedom to move in larger spaces, the amplitude of the vibrations becomes enlarged at the expense of their rapidity, and it requires an enormous increase of motive power to restore the rapidity in the face of the ever-augmenting

amplitudes. This consideration is very adverse to the supposition of solar light's being due to incandescence.

It might be argued, however, that by the great pressure of the heated vapours, a certain portion of the mass of the sun may be prevented from assuming the vaporous condition, and may therefore glow with a very intense degree of incandescence. It might be further maintained that the hot vapours, acting as partial absorbents, may produce the fixed lines of the spectrum. This view has been upheld by several philosophers—more especially since the discoveries of M. Kirchhoff, tending to establish that the solar radiation does, in the course of its journey towards the earth, traverse the vapours of certain known substances which absorb definite waves, so giving rise to the spectral lines. It is only this facility of explaining the formation of those lines, however, that gives plausibility to this view, which is otherwise open to almost insurmountable objections.

In the first place, it leaves without any satisfactory explanation the phenomena of the willow-leaf-shaped bodies of Nasmyth, the faculæ and the spots—more especially the connection between the spots and terrestrial magnetism. It entails the necessity of supposing the spots to be not partial denudations of the surface of the photosphere, but dense masses superincumbent on the glowing surface of the sun's nucleus—a supposition discountenanced by the phenomena observed when a spot approaches the edge of the disc, and indeed, as already pointed out, irreconcilable with nearly all the phenomena which the spots present.

The supposition of an incandescent nucleus is also discountenanced by the proportion which the heating power of the solar radiation bears to its brightness. Were solar light due to incandescence, it ought to exert a heating power corresponding to that by which it is generated; but on comparison with the radiation proceeding from incan-

descent lime, it is found, as already mentioned, that for equal degrees of brightness, the radiation of the sun has less than a fourth of the heating power exerted by that from the lime. In this particular the radiation from the sun agrees more nearly with that from the electric light, produced between charcoal points. For Professor Tyndall has ascertained that the radiation from platinum wire, rendered white-hot by an electric current, exerts about two and a half times more heating power in proportion to its brightness than does the electric light. Did the solar radiation, then, proceed from an incandescent mass, the proportion of waves of long period which it would contain would be greater than it is found actually to possess.

The chief difficulty, however, with which the theory of incandescence has to contend is the question of supply. Were the radiation of the sun that of an incandescent body, it would be continually diminishing, and the amount of light and heat which the earth derives from it would be much less now than it was in ancient times. But of such a diminution we have no evidence whatever. The mean temperature of our globe is still the same as it was in the earliest historic times. To obviate this difficulty some philosophers have devised a hypothesis which has, at first sight, a certain amount of plausibility. They imagine the supply of light and heat to be maintained by the continuous falling of meteors into the sun. These bodies, they suppose, encountering resistance to their progressive motion from the ether, have their orbits so reduced that they at last become entangled in the gaseous envelopes of the sun, and their progressive motion there meeting with still further resistance, they fall ere long upon the surface of the solar orb. The force, however, by which their progressive motion was maintained is not lost by this collision. It merely changes its mode of operation; and, instead of progressive motion, it now produces an equivalent amount

of vibratory motion, which manifests itself in the form of luminous waves.

It was at first proposed to fetch these meteors from beyond the limits of the solar system, and make them plunge straight into the sun. But it was soon perceived that by this process the mass of the sun would be continually augmenting, his force of gravity would be in like proportion continually increasing, and such an augmentation could not fail to manifest itself by a diminution in the periodic times of the planets. The absence of any such phenomenon put that notion out of the question. It was next sought to confine the source of supply to meteors circulating within the orbit of Mercury. For although such meteors, by falling into the sun, would augment his mass, they would not increase the amount of gravitating attraction acting on the planets, seeing that all the matter, included within the orbit of Mercury, would exert the same amount of gravitating attraction on that planet and those exterior to it, whether such matter were agglomerated into one mass or separated into several. Here, however, the theory is met by a new difficulty; for, as will hereafter be more clearly shown, such a restriction of the source of supply renders it utterly inadequate.

But, in truth, this theory is founded on an assumption which is quite gratuitous—namely, that meteoric bodies, or small planets revolving round the sun, must be resisted in their progress by the ether. The only shadow of evidence in favour of such a notion is the observed diminution in the periodic time of Encke's comet. But that phenomenon has received a different, and far more reasonable, explanation, to which reference has already been made.

If, again, in the theory of incandescence, it be sought to dispense altogether with a renovation of the supply, by supposing the original temperature of the sun to have

been so amazingly high that the loss of heat, at the present rate of radiation, would be so comparatively small that it might escape detection, this modification of the hypothesis will be found irreconcilable with other facts and phenomena, as will be shown in the next chapter.

The idea of the sun's being an incandescent mass is thus so little capable of commanding assent as to render it needful to have recourse to some other hypothesis.

The objection arising out of the question of supply tells with still greater force against the idea of the sun's being a body in a state of combustion; for the chemical forces by which any such combustion could be maintained would long ere now have been utterly exhausted, and could nohow be renewed. This point will be also established more clearly hereafter.

We seem, therefore, limited to the photosphere itself, as being the seat of the force by which is maintained the vibratory motion manifested in the solar radiation. This view is strongly supported by the phenomena of the willow-leaf-shaped bodies and those of the spots. From these may be legitimately drawn the following conclusions.

There are on the surface of the sun four gradations of brightness. First, that of the faculæ, which have the greatest splendour of all; secondly, that of the general surface of the photosphere; thirdly, that of the penumbra of a spot; and fourthly, that of the umbra of a spot. If the nucleus have any brightness at all, it is quite inappreciable. That of the umbra is so feeble as to be discernible only by contrast with the blackness of the nucleus. If the light be generated in the photosphere, this feebleness of the umbra is easily explained by supposing that region to consist of vapours floating in an elastic medium, and having a power of reflecting in a moderate degree the light falling upon them from the photosphere. Such

reflected light would of course appear very feeble, in comparison with the direct light coming from the surrounding brighter regions. This view is favoured by the roundness of the outline, which separates the umbra from the nucleus.

The gradations of brightness in the penumbra, the general surface of the photosphere, and the faculæ, tend to establish the fact that the willow-leaf-shaped bodies are not only self-luminous, but that they do not intercept each other's light, and are floating in a perfectly transparent medium. The faculæ are obviously produced by the heaping up of the light-generating bodies into masses of greater thickness than the general photosphere. But this superposition of luminous laminæ could not increase the brightness, unless each layer allowed the light from those behind it to pass through, and so produce an accumulation of splendour. In like manner the luminous material, heaped up in the faculæ, has evidently been swept from those portions of the general surface of the photosphere which form the spots and their penumbræ. Hence the comparative faintness of the light of the penumbral regions. The general surface of the photosphere again must obviously consist of several layers of the luminous bodies, in order to its having a brightness so much beyond that of the penumbræ. From this constitution of the photosphere it follows, that spots on the sun do not interfere with the constancy of the amount of radiation emanating from that luminary.

The above phenomena, which can be all easily explained on the supposition of the light's being generated by the willow-leaf-shaped bodies constituting the photosphere, are nearly inexplicable in accordance with the hypothesis that the light proceeds from an incandescent central mass. Neither does it appear possible to hold the willow-leaf-shaped bodies to be themselves solid incan-

descent masses. Their suffering each other's light to pass freely through them seems to exclude such a notion. This transparency, however, is consistent with the supposition that these remarkable bodies may be of the nature of flames, because all flames are more or less transparent. But it is impossible to believe them to be flames produced by combustion ; because the action of the chemical forces by which any such combustion might be maintained could not be indefinitely prolonged, and, as will hereafter more clearly be shown, it would long ere now have ceased. The question thus arises—whether the self-luminosity of the willow-leaf-shaped bodies may not be due to electricity.

That the surface of the photosphere is in a highly electric condition is proved by the violent repulsion which it exerts on the matter composing the tails of comets. Such a repulsive force seems inexplicable on any other supposition than that of its being electrical. The intimate connection between the solar spots and the terrestrial phenomena of the aurora borealis and the disturbances of the magnetic needle, also corroborates the idea of there being a large amount of electric tension developed at the surface of the sun. In a more especial manner, the remarkable luminous phenomenon observed by Messrs. Carrington and Hodgson, already mentioned as having appeared on the sun's disc, and been followed by a most violent disturbance of the magnetic needle and an unwonted display of the aurora borealis, confirms this view. For it gives additional proof that electrical changes on a great scale do occasionally take place in the solar photosphere, and do exert a marked influence on the magnetic and electric condition of our own globe.

The aurora borealis itself furnishes, in some particulars, a striking analogy to the light of the photosphere. This beautiful phenomenon may be imitated artificially,

by passing electrical discharges through a highly rarefied gaseous medium. If the vacuum be perfect, the discharge will not pass. There must be a continuity of ponderable substance to form a medium for the transmission of the electrical condition. If, on the other hand, the medium be comparatively dense, such as atmospheric air in its usual state, the electrical discharge is accompanied only by a succession of sparks, which, being mere points, produce little luminous effect. But if the atmospheric air, or other gas, be considerably rarefied, these sparks expand into broad flashes of great brilliancy, much resembling the streamers of the aurora. If a series of tubes containing the rarefied air be placed behind each other, and continuous electrical discharges be kept passing through them, there may be obtained a great intensity of light, which may be indefinitely increased by adding to the number of tubes. When the rarefaction is carried to a certain pitch, a curious effect is produced. The flashes become stratified by dark bands symmetrically arranged. These appear to be caused by interruptions in the continuity of the discharge, which takes place by pulses rather than by a continuous flow, probably in consequence of the medium's being thrown into waves of unequal density. To produce these striæ it is indispensable that the gaseous medium be perfectly dry. The nature both of the gas and the glass employed also greatly modifies the colour and general appearance of the electric flashes, as well as the aspect of their striæ.[1]

Another remarkable property of those luminous discharges is their relation to magnetism. They always tend to place themselves in a direction transverse to that in which iron would be attracted by the magnet, and the

[1] Tubes are now made containing rarefied gas along with a mercurial amalgam, and bent into a zig-zag. On its being moved by the hand, so as to cause the amalgam to flow from end to end of the tube, there is excited, by its friction on the glass, so much electricity as to render the gas luminous.

flame may be actually made to rotate round the pole of a magnetic bar, introduced into the tube through which the discharge is passed.

These beautiful phenomena are highly suggestive. They indicate the possibility that the light of the photosphere may be produced by electrical discharges, passing through a highly rarefied and very dry gaseous medium. The tendency to stratification might even go far to explain the apparently determinate forms which the solar light-generators exhibit. The behaviour of the electric flames under the influence of a magnet would also be in harmony with the explanation which has been given of the formation of the spots, by the influence of highly magnetic small planets acting in conjunction. For supposing such to be the true origin of the spots, the flames proceeding from electrical discharges would, by the action of the magnetic bodies, be dispersed laterally, placing themselves in rays directed towards the centre of magnetic force, and revolving round that centre, like the artificial aurora round the poles of a magnet. Such a rotation of the luminous rays of the penumbra of a spot has been observed by Mr. Dawes.

This theory, however, is open to two objections. Professor Stokes has found, as already mentioned, that by using prisms of rock crystal, and receiving the image on a highly fluorescent surface, the visible portion of the spectrum becomes greatly extended towards the violet end. But the solar spectrum, on being compared with that from the electric light under such circumstances, exhibits a considerably smaller amount of elongation. This fact is adverse to the idea of solar light's being of the same nature as that produced by an electrical discharge. The difficulty, however, might be obviated, as already pointed out, by supposing the radiation from the sun to lose a portion of those very short waves, in passing through

the medium in which are produced the rose-coloured prominences before described.

The other objection is less easily removed. How are we to account for so vast an accumulation of electrical discharges, as must go to constitute a photosphere 400 miles in thickness, and of such intense brilliancy? The splendour, indeed, is simply the result of this immense thickness, and could we account for electrical discharges pervading so enormous a stratum of very rare gases, the mere brightness would present no difficulty, seeing it might be caused by the cumulative action of the transparent electrical flashes. The difficulty consists in the thickness which it is needful to assign to the stratum, and in finding a source for the inexhaustible supply of electric tension. In the case of the aurora borealis, the electrical discharges probably pass between masses of air which have acquired opposite states of electrical tension, through the condensation of aqueous vapour, near the limit of absolute dryness. When moist air approaches this limit and becomes chilled, the moisture will condense and fall downwards, till it either forms a cloud or becomes re-absorbed by the atmosphere. But whenever aqueous vapour thus condenses, it communicates electric tension to the dry air, and when the tension reaches a certain point, and the air is sufficiently rarefied, a discharge will probably ensue. Such an operation as this, however, could never extend to any great thickness; and hence it is that the aurora has always a thin and filmy texture, transparent even to the feeble light of the stars. There is accordingly great difficulty in conceiving of such an operation's producing electrical discharges, passing layer over layer through a great thickness of rarefied atmosphere. The more probable supposition appears to be that, if the solar light be electrical at all, it consists of discharges passing either between the willow-leaf-shaped

masses viewed in their integrity, or between comparatively minute bodies composing those masses.

The definiteness of the forms assumed by the solar light-generators suggested to Sir John Herschel the idea of their being solid consistent masses of some kind, and led him to conjecture that they might be organic bodies, specially designed for the generation of the light. He hesitates about assigning to them vitality—admitting nevertheless that life has the power of producing vibratory motion, which may assume the form of light, heat, actinism or electricity.[1] It seems useless, however, to imagine these bodies to be organic, without also supposing them to be endowed with motive energy; for it is only this latter supposition that is of any value, in accounting for the inexhaustible supply of motive force, by which the vibratory motion may be maintained. The suggestion that each of the willow-leaf-shaped bodies may be in itself one vast light-generating organism would also be of little avail; for the light-producing property must in that case be confined to the surface of the mass. But the great intensity of the light is much against that idea: and so is the accumulation of brightness by the superposition of layer upon layer as seen in the faculæ. It is also rendered improbable by the vast dimensions of the willow-leaf-shaped bodies, the average being about 1,000 miles in length, by about a tenth of that amount in breadth. The difficulty would be much lessened, by conceiving each of these willow-leafed-shaped masses to be composed of a vast congeries of very minute bodies having the property of generating light; for the great brightness would in this case be easily explained by the accumulation of effect. The light generated by each individual body in the mass might be of very moderate amount; but

[1] See *Good Words*, April 1863. For a similar suggestion of an earlier date, see *The Year-book of Facts*, 1857, p. 135.

the immensity of the number of points from which the light might emanate, and their superposition layer upon layer, would suffice to produce, at the general surface, an intense splendour. This view is strengthened by the change of form which these bodies undergo, in passing from the willow-leaf to the rice-grain shape—a change not easily explicable on the supposition of their being single large masses, but easily explained by supposing them to be composed of numerous very small individuals. For the rice-grain shape becomes elongated into the willow-leaf shape, when the mass begins to move rapidly in the direction of its length. If, then, we are to suppose these masses to have any solidity at all, it appears further needful to imagine them to be vast assemblages of very minute bodies, affecting those definite forms in their aggregation. In considering this question, it must be borne in mind that, although, from the distance at which they are viewed, these bodies appear to have a definite regular outline, that outline may in reality embrace many irregularities, such as an assemblage of small bodies might present. So also, although the groups, viewed from so great a distance, appear very close together, they may nevertheless be separated one from another by intervals of several miles. Thus, while the members composing each group may be close together, the groups may be so far apart as to form totally distinct masses of an elongated form.

Supposing these remarkable masses, then, to be thus constituted—to be aggregations of very small luminous bodies, it would not be needful to assign, to each individual constituent of the mass, more than a very moderate amount of luminosity. The light of the sun is about a million and a half times more intense than that of an ordinary wax candle of six in the lb. Now, assuming the whole of the sun's light to emanate from the photosphere,

and only half of it to be transmitted outwards—assuming, further, that the thickness of the photosphere, as determined from the thread of light which always separates the penumbra of a spot from the solar limb, is about 400 miles, then it will follow that the light radiating outwards from each square inch of the solar surface is contributed by about twelve millions of cubic inches. Hence, any number of small bodies, occupying a cubic inch of space, provided they be so small compared with the intervals between them, as not materially to intercept the radiation, but to allow it to pass freely, would, in order to accumulate by superposition a brightness equal to that presented by the surface of the photosphere, have to contribute only about an eighth of the light of a wax candle, or less than half of that given forth by the South American fire-fly.

In like manner, assuming the solar heat to be also generated within the photosphere, and only half of it to be radiated outwards, it has been already shown to be unnecessary to suppose more than half a degree F. of constant temperature to be generated within each cubic inch —an amount much less than that maintained by many animals. Hence, supposing the generating bodies to be very small, and so constituted as to be little capable of absorbing heat, while they freely generate and transmit it, there would be no need for assigning to each minute body more than a very moderate temperature.

There is yet another mode, however, of explaining the origin of at least a portion of the heat. It has been already stated that certain media have the power of lowering the rates of vibration, and increasing the lengths of the waves transmitted through them. This they appear to do by taking up the motion from the ether, when, in virtue of that acquired energy, their ultimates begin to vibrate at a slower rate than that at which the ultimates

of the ether, whose energy they imbibed, were previously vibrating. These vibrations in the ultimates of the medium propagate through the ether fresh waves, which have the slower rate and longer wave-length prevailing among those ultimates. Now, this may be the constitution of that elastic envelope in which are produced the red prominences, and which invests the photosphere, though probably at some considerable distance from its surface. If this hypothesis be correct, it will become allowable to suppose the waves generated in the photosphere itself to be for the most part of short period, consequently possessed of but little intrinsic heating power; while it is not till the passage of the radiation through this elastic medium, that it acquires any large proportion of waves of long period, arising from the conversion of the shorter waves generated in the photosphere. It will be presently shown to be probable, that the radiation, in passing through this medium, is deprived of a very considerable portion of its luminous waves; consequently it is fair to suppose these waves to be converted into others of long period, which, while invisible to the eye, have a large power of communicating heat. This hypothesis, while thus attributing to the medium in which the red prominences are produced a highly useful office, would also enable us to assign to the photosphere itself a very moderate warmth.

Still confining attention to the idea of the solar light's being somehow or other generated in the photosphere itself, and not in the body of the luminary, or derived from any extraneous source, it remains to be considered how the fixed lines of the spectrum are to be explained in accordance with this supposition. The light of the photosphere, however generated, would produce a continuous spectrum, unless the radiation were to pass through the vapours of certain substances capable of absorbing those definite waves, which appear as dark lines in the spectrum

obtained from solar light. On this point, there are three views which may be entertained. It has already been pointed out that the elastic medium, in which the red prominences are exhibited, may possibly be a gaseous shell at some considerable distance from the surface of the photosphere, and separated from it by a space containing nothing but the free ether. This idea is based on the fact of there being a space sometimes observed between the red prominences and the solar disc. Granting that the surface of the photosphere is continually in a state of high electric tension, and seeing no discharge of electricity can pass through the free ether, the surface of the photosphere might exert on this gaseous shell such a repulsive action as would exactly countervail its tendency to approach the sun by virtue of its gravitating attraction. Now this shell may contain the vapours of all those substances, whose characteristic lines can be detected in the solar spectrum, and it may be here that those definite waves are absorbed.

It is not necessary however to suppose the vapours producing the fixed lines to be placed so near the sun, as the medium exhibiting the red prominences. They may form a vaporous ring of a breadth somewhat exceeding that of the ecliptic, and removed as far away from the sun as may be consistent with their retaining a temperature sufficient to maintain the vaporous condition. Considering the great heating power which the solar radiation exerts on bodies capable of absorbing it, this distance may be considerable.

But even this degree of proximity is not indispensable. It is found that, when substances are placed at the poles of an induction coil, they are thrown into vapour with great ease, and that this action is due, not so much to any very intense heat there developed, as to the repulsive action of the electricity itself. The constituent ultimates

of the substance become individually and similarly electrified, and are thus rendered mutually repellent to such an extent as to overcome their cohesive attraction, and cause them to assume the vaporous condition. Now, were a substance, thus electrified and thrown into vapour, to be placed in the free ether, it could not spontaneously alter its condition; because no discharge of electricity can take place through the free ether, which is incapable of either assuming or transmitting the electrical state. The substance, therefore, thus preserving its electrical, would also retain its vaporous condition, and that although its temperature might be very moderate.

Now, the lenticular mass of matter, which, by reflecting the solar rays, gives rise to that beautiful phenomenon the zodiacal light, may be, to a great extent, composed of substances in this vaporous condition, by reason of their ultimates being perpetually electrified, and so prevented from exerting their cohesive or chemical attractions. The faintness and transparency of the zodiacal light, resembling that of the tail of a comet, render it more probable that the reflection of the sun's rays proceeds from a vaporous mass, rather than from a collection of small solid bodies, as some have supposed. Now, it is certain that the solar rays do pass through the matter which produces the zodiacal light, and if that matter be vaporous, they must suffer a certain amount of absorption in their passage. This absorption may manifest itself by producing the dark lines of the spectrum.

The vaporous shell exhibiting the red prominences, however, seems to be the most probable site of the absorption of those lines. This probability has been recently strengthened by a curious fact which has fallen under the notice both of Mr. Lockyer and M. Rayet. When examining with the spectroscope one of the red prominences on separate occasions, they observed the sodium

lines to be reversed—bright instead of dark. This observation proves that the vapour of sodium does exist in the chromosphere, and manifests its presence when it is rendered incandescent by a sufficiently powerful electrical discharge. Father Secchi has also observed that all round the sun, at the inner edge of the chromosphere where the heat must be greatest, several of the dark lines of the spectrum become faintly luminous.

The difficulty in explaining the formation of the fixed lines, in accordance with the supposition of solar light's being generated in the photosphere, is therefore not insurmountable, nor even very formidable; while it is only in this single point of easily explaining the fixed lines, that this hypothesis can be regarded as inferior to that of the light's proceeding from an incandescent nucleus, closely enveloped in highly heated and partially absorbent vapours. But its inferiority on this point should not be allowed to outweigh its superiority in every other respect.

To enable us, however, to weigh more accurately the probabilities attachable to these two opposite views, it is needful to cease from regarding the solar radiation as either light or heat, and to examine it under the aspect presented in the following chapter.

CHAPTER XI.

SOLAR ENERGY.

In the foregoing investigations, what emanates from the sun has been regarded as radiant light and heat; but for a more thorough comprehension of the subject, it is needful now to view it simply as motive energy or mechanical force.

The heating power of the solar radiation, at the outskirts of our atmosphere, has been shown to be capable, when wholly absorbed, of communicating to 1 lb. of water 0°·1544 F. per square foot of surface, in the first second of time—at least this has been shown to be a probable estimate of its effects. The mechanical equivalent of heat, as determined by Mr. Joule, is 772 lbs. raised a foot high, for every 1° F. imparted to 1 lb. of water. Adopting the lowest estimate of the sun's distance and the highest of the earth's specific gravity, it may from these data be shown, that the solar radiation would be capable of raising more than twenty-two times the weight of our globe a foot high in a second.[1]

On this basis it is not difficult to determine how long the mechanical force of the sun, at its present rate of emanation, could be supplied by combustion. Carbon being the substance which, of all others, gives by burning the highest mechanical equivalent, it may be shown by calculation, that a mass of carbon, equal in weight to our

[1] See note I.

globe, would afford a supply for less than six days. It may in like manner be shown that were the sun composed of nothing but carbon, and the requisite amount of oxygen for its combustion, the supply of energy capable of being furnished by this source would be exhausted in about 1430 years.[1] It is thus rendered manifest that combustion is quite inadequate as a source of supply.

Let us now see how far the requisite energy might be furnished by meteors continually falling into the sun. It may be shown by calculation that a quantity of meteors equal in mass to the earth, falling successively into the sun, would supply an amount of mechanical force equivalent to that exerted by the solar radiation for a period of a little less than forty-six years.[2] Now, as the sun contains, on a moderate estimate, about 331,297 masses equal to that of the earth, it is plain that, supposing his orb to have been formed by meteors falling successively into an originally small central nucleus, there is here abundance of material to have furnished an adequate supply of energy for a vast period of past time—possibly between seven and eight millions of years.[3] So far, therefore, as regards time past, there is no fault to be found with the meteoric theory, in respect to the adequacy of the supply of motive energy. It is only when it comes to be applied to the present and the future, that its inadequacy becomes manifest.

It has already been pointed out that the present and future supplies must be derived from meteors circulating round the sun within the orbit of Mercury. Now, Leverrier has shown that, owing to certain minute disturbances in the motion of that planet, it is very probable that there does exist a ring of meteors between it and the sun. But he has further shown, that the united mass of the meteoric bodies composing such a ring cannot, with any prob-

[1] See note J. [2] See note K. [3] See note L.

ability, be estimated at more than that of the planet Mercury itself. Now, it is easy to prove by computation that the supply of motive energy from this source could not last beyond eight years.[1]

With a view to obviate this difficulty, it has been sought to modify the meteoric theory so far as to suppose that, while the sun was originally formed by the successive accumulation of meteoric bodies, during a long epoch of the past, somewhat in the manner already indicated, the heat generated by the conversion of the progressive motion of those bodies into molecular vibrations, has, during the whole period of human history, been gradually given off without renewal, or at least without a supply anything like equal to the continuous loss. In other words, it is supposed that, for a long time past, the sun has been gradually cooling. This view, however, has to encounter a not less formidable difficulty; for it can be shown by calculation, that it would involve a decrease in the sun's apparent diameter so great and so rapid that it could not have escaped detection. It would also involve a diminution in the amount of solar radiation received by the earth, much beyond any of which we have either historical or other evidence.[2]

The fact already mentioned that, for so long a period as 2,580 years there has been no diminution in the earth's temperature capable of detection by astronomical phenomena, is a strong indication that the motive energy, which emanates in the form of solar radiation, depends for its continuous supply—not on any accidental, or uncertain and variable source, but on some permanent unvarying means of compensation regulated by determinate laws.

The meteoric theory is thus beset with difficulties on all sides, and presents no advantage, except the single

[1] See note M. [2] See Note N.

one of explaining in what manner the sun may have originally acquired a very high temperature. For, as above shown, it will not do to suppose the sun to have been continuously losing heat during the historic period ; while the smallness of the united mass of meteors within the orbit of Mercury at the present time, shows such a source for supplying the waste to be quite inadequate.

Let us now revert to the idea, that the motive energy proceeding from the sun is generated within the sun itself. And here it is needful to cease from regarding that energy in its entireness, and to view it somewhat more in detail. Notwithstanding the greatness of its total amount, it is easy to show by calculation, from the data already adduced, that the force, generated in each cubic foot of the solar photosphere, is probably not more than would suffice to raise about five pounds and a half a foot high in a second.[1] To aid us in forming a conception of this amount of force, we may, for the sake of comparison, have recourse to the analogy furnished by the amount of motive energy put forth by living organisms in our own globe.

Man and the vertebrate animals in general put forth, on an average, a force equivalent to raising two-thirds of their own weight a foot high in a second. Thus a man of the average weight of 150 lbs. will raise 100 lbs. a foot high in a second, while his bulk will be about two and a half cubic feet. His force, therefore, corresponds to 40 lbs. raised a foot high in a second, for each cubic foot, or upwards of seven times that which it is necessary to suppose to be generated in each cubic foot of the solar photosphere. But recent experiments, made independently by Professor Plateau and M. Felix, show that the motive energy exerted by insects is proportionally much greater

[1] See Note O.

than in the case of the vertebrate animals. The common cockchafer *Melolontha vulgaris* exerts a force equivalent to fourteen times, and *Donacia nymphæa*, a small beetle, to forty-two times its own weight raised a foot high in a second. This last is therefore, in proportion to its weight, more than sixty times stronger than man. These observers have both found that, in insects of the same family, the smaller and lighter the species, the stronger is it in proportion to its weight. The above examples may suffice to show that the amount of energy which living beings may exert within a given amount of space, may far exceed the highest estimate of what it may be necessary to suppose to be generated within each cubic foot of the solar photosphere.

There is this important point, however, to be kept in view, that terrestrial organisms only *exert*, but do not *generate*, the motive energy which they put forth. They must, through the medium of their food and respiration, be supplied with this energy in one form or another—be it electric tension or heat.

Further, to illustrate this matter, let us consider what occurs in the ordinary combustion of carbonaceous substances. The light generated in this process is due simply to the extreme rapidity with which the carbon unites with the oxygen of the atmosphere; and the intensity of the light may be greatly augmented by merely increasing that rapidity in a high degree, as by burning the carbon in pure and highly compressed oxygen. As soon, however, as the combination is effected, and the resulting compound, carbonic acid gas, is formed, all further action ceases, and no more light is produced. The source of the luminous vibrations here is not a motion already existing either in the carbon or in the oxygen. The true cause of the motion is the opposite electrical condition of the two elements, causing them to fly into

union, and in so doing to generate vibrations. Electricity, subsisting in a latent state, is what is really stored up in the carbon and oxygen, and rendered active by heat. It is this electrical tension which, on its becoming exhausted, has to be restored to those elements.

Now, terrestrial examples show the living beings, which organize plants, to be capable of restoring this electrical tension to both oxygen and carbon—detaching the latter from its combination with the former, and causing it, by their organizing energy, to enter into the structure of the plant. The carbon and oxygen are thus, by the influence of life, brought into their former condition, and rendered fit to enter into combination with each other anew, and so to produce a fresh quantity of vibratory motion, manifesting itself in the form of luminous waves. The motive energy, exhibited in these last, is thus traceable to life as its immediate source. Now, as the whole of our coal strata, and all vegetable substances, have been formed by this action of the living beings which organize plants in decomposing carbonic acid gas, all the light and heat which we derive from the burning of such organic substances as fuel, are in like manner traceable to the agency of life, as the source of that electrical tension, in virtue of which these substances produce motion while combining with oxygen. Without the influence of life, the light and heat derived from fuel would never have existed.

It is moreover found that the carbonic acid gas contained in the earth's atmosphere is a constant quantity; so that the whole of that gas which is being continually formed by the various processes of combustion and animal respiration must be as continually decomposed by the action of living plants. There is here accordingly a striking example of the manner in which life may act indirectly, in furnishing a perpetual supply of materials,

from whose action one upon another light may be derived.

True, the living organizers in this case require the aid of the motive energy coming from the sun to effect this compensation. In the particular act of decomposing carbonic acid gas, however, the part performed by the solar radiation is secondary. It serves merely to excite those vibrations which predispose the combined elements to yield to the decomposing powers of the living organizers.[1] It renders the carbonic acid gas decomposable, but does not itself effect the decomposition. It is like the initial heat applied to cause carbon to combine with oxygen. That initial heat is merely a predisposing agent, but not the source of all the light and heat evolved in the combustion. When a powder magazine is exploded by a spark, the tremendous mechanical force exerted by the explosion can never be said to be the representative of the small amount of heat supplied by the spark. So, also, when a gasometer, filled with chlorine and hydrogen gases mixed in the proper proportions, is exploded by the actinic rays of the sun, it would be idle to affirm that the whole mechanical force developed in this case is the equivalent of the motive energy supplied by those actinic rays. In both of those cases, the great mechanical force developed has its source in the electric tension of the elements, and is exactly proportional to the amount of that tension. So the sunbeams act on the carbonic acid gas of the atmosphere as a predisposing agent, but are not the source of the electric tension, which the oxygen and carbon acquire on being separated from each other. The true source of that tension is the living organizer of the plant, by which the decomposition is effected. The organizer, however, does

[1] The red and yellow undulations are those which are specially active in this case.

not *generate* the tension; for all the motive energy which it puts forth in decomposing the carbonic acid it derives from its own appropriate food.

Take as another analogy the case of the magnetic tension developed in steel bars by the method of touching. Here the tension is the representative of the mechanical force put forth by the operator; while the magnetism of the touching magnet is merely the intermediate agency, of which the operator avails himself, for converting his active muscular force into the statical form of permanent magnetism. This last may, in like manner, become available for enabling the operator to convert his muscular force into electricity and light, by the permanent magnet's being made the principal element in a magnetic electrical machine. In this case, the statical force of the permanent magnet is not what becomes light and electricity; for it remains without waste or change. It is the muscular force of the operator which, by means of the magnetism, is changed into electricity and light. But here again the muscular power of the operator is not actually generated by himself. It is derived from his food and respiration.

It is accordingly needful, in reasoning from such analogies, to bear in mind that all the motive energy put forth by terrestrial organisms may be regarded as simply the motive energy of the solar undulations reproduced in another form; because the living beings, which construct such organisms, whether animal or vegetable, depend either directly or indirectly for the development of their powers on the motive energy derived from the sun. But, on the other hand, the solar undulations cannot of themselves either generate life or become converted into life. In support of such a notion, we have no evidence whatever. Neither can the motive energy of the sunbeams pass into vital energy of itself, in virtue of

any general law. This idea is equally destitute of support. To effect the conversion, there is required the intervention of that third somewhat which we call a living being. This is the real agent in changing mechanical force into vital energy and *vice versâ*. It is quite certain that the sunbeams might pass for ever through the atmosphere, without decomposing a single molecule of carbonic acid gas. But by their stimulating into action a living being, endowed with powers specially adapted to the purpose, and also by their exerting a predisposing influence on the gas itself, the decomposition is effected. Now seeing the sunbeams have in themselves no special power to decompose the gas, while the living being has such special power by the help of the sunbeams, it appears more reasonable to regard the electric tension imparted to the carbon and oxygen, on their disengagement from each other, as being the representative of the special faculty of the living being, than of the mere mechanical energy of the sunbeams. It is in reality, however, the result of the conjunct action of the solar radiation and the living being; and it could not be produced by either of these acting alone.

The necessity for such a conjunct action will appear more manifest from a consideration of the inadequacy of terrestrial organisms for self support, independently of the energy derived from the sun. For if the quantity of motive energy contained in the sunshine falling upon a square mile of terrestrial surface, be compared with the motive energy contained in the food which may be obtained from that surface, as measured by the force which animals fed on it could put forth, the latter will be found many times less than the former.[1] The power of the sunbeams is accordingly far beyond what could be produced

[1] See note P.

by the mere interchange of force between the animal and vegetable organisms of our globe.

While there can be no doubt, then, that all the motive force, displayed by terrestrial living organisms, is only a portion of the energy of the sunbeams in another form, we must, on the other hand, recognise a special power in the living beings themselves—that, namely, of converting one species of force into another. But there seems little reason to doubt that they are capable of exerting other powers peculiar to themselves, the results of which cannot be regarded as the equivalents of any purely mechanical forces already existing in mere matter.

Take the familiar case of human thought. Man cannot exercise his intellectual, any more than he can his physical, powers without food; but the food ought not, therefore, to be regarded as the origin or cause of his thoughts. Neither can thought be deemed the representative of the food. The two things are incommensurable, and incapable of mutual comparison. It cannot be affirmed that a pound of food will produce so much thought, in anything like the same sense in which we can say that a pound of food will produce a certain equivalent of muscular action, or that a pound of fuel will produce so much heat, which may be employed to raise a certain weight a foot high. The food, in its relation to thought, acts somewhat like the spark applied to the powder-magazine. The vast mechanical force attending the explosion represents the motive energy, not of the tiny spark, but of that statical power which was treasured up in the gunpowder. So human thought does not represent the food digested in the human stomach, but is the result of the innate powers, with which God has endowed the living being, man. It is in the motions requisite to maintain the mechanism of his organism, and those which he voluntarily performs, that

we are to seek the equivalents of the physical energy imparted by the food which he digests, and the oxygen which he inhales. But his thoughts are something beyond all these, and are the manifestations of man's inherent powers as a rational living being; notwithstanding that the exercise of the power of thought may involve a certain amount of chemical change in the tissues of his organism, and certain minute mechanical motions in their constituent ultimates.

The lower animals, again, may not have exactly what we call thought, but they have various instincts, which may, in like manner, be regarded as the results of their inherent powers as living beings, apart from the physical forces exhibited in their organisms, which may properly be deemed the equivalents of the motive energy imparted to them by their food and inspired oxygen. Instinct is in fact the controlling power of the living being, regulating the manner in which the motive energy of the organism is to be exerted.

Our investigation has now reached this point. It has been shown that, assuming the sun not to be simply an incandescent body in the progress of cooling, two possible views may be entertained respecting the origin of its motive energy, consequently of the light and heat which it radiates—the one that it is derived from without, from meteoric bodies continually falling into the sun, the other that it is in some manner generated within the sun itself, either in the photosphere or on the true surface of his nucleus.

According to the former of these views (not less than to that of the sun's being simply a cooling incandescent body), the motive energy in the universe is a definite quantity; what was its origin being left to conjecture. This definite quantity is being perpetually dissipated through the infinite ether; and no reasonable hypothesis

has yet been framed to show how it may be restored to its centres. Neither is there any provision for its being renewed by any other means. It is thus quite analogous to the mainspring of a watch which has once been wound up, and is now in the course of running down, with no appliance for winding it up again. This theory assumes that there is no motive energy ever generated. There is merely a continuous transformation of one kind of it into another—resulting in its final dissipation through the ether in the radiant form. According to the other view, the motive energy that is being thus perpetually dissipated, is actually generated in the several centres whence it emanates, and is continually renewed by some means or other adequate to the purpose.

The foregoing investigation has further shown that the second of these views presents several advantages over the first in the explanation of solar phenomena—especially those of the spots, the faculæ and the willow-leaf shaped bodies of the photosphere. It has been demonstrated, moreover, that the amount of motive energy, which it is needful to suppose to be generated in the sun, within a given space in a given time, is not so great as might, on a cursory view, be imagined; that it may not be greater indeed than what the living beings which inhabit terrestrial organisms are capable of exhibiting in a like given space and time, whether in the form of mere mechanical force or of luminous or thermal vibrations. It has been pointed out, on the other hand, that such beings, so far as our experience goes, never actually generate the motive energy which they display. Nevertheless, they are endowed with special powers of converting one sort of motive energy into another, as also with other special powers, such as thought, reason, instinct, volition, &c., which cannot be reasonably regarded as mere modes of motion, derived from pre-existing mechanical motions of another kind;

although they may, in their exercise, involve certain motions of the material ultimates within the organism.

The origin of the motive energy is not, however, more of a puzzle on the supposition of its being generated in the sun itself, than it is on the other supposition, that the motive energy of the universe is in course of continuous dissipation, and never renewed at all. For the most able natural philosophers have shown it to be impossible to imagine matter itself to have originally generated the motive energy existing in the universe. They allow that it must have had an extraneous source, and that, seeing a large portion of the motion is regulated by mathematical laws of great beauty, its source could be nothing but an Intelligent Mind. According to the fixed quantity and continuous dissipation theory, then, this Intelligent Mind, having by mere volition generated a fixed amount of motive energy, and so arranged matters that this energy should be in a continual state of dissipation, omitted to make any provision whatever for its perpetual renewal. According to the other view, there was no such omission in the intelligent arrangements of this great designing mind; but in each of the self-luminous orbs of the universe, provision has been made for a continual generation of motive energy, to supply the waste attending its perpetual dissipation in the radiant form.

Of the manner in which this motive energy is thus renewed, we are as ignorant as we are of the manner in which the motive energy pervading the universe was originally generated. But while it is not unreasonable to suppose that, in the first generation of motion, the Creator may have acted immediately, and by a simple exercise of will, it is more consonant to reason to suppose that, as regards the provision for its perpetual renewal, He acts mediately, through the intervention of instruments adapted for the purpose, seeing that is the only manner

of his action of which we have any experience. What may be the nature of the instrumentality employed we know not, and are never likely to know. Our wisest course, therefore, is to regard the origin of the motive energy emanating from the sun and fixed stars, as one of those mysteries of nature, which it has not been put within the power of the human mind to solve.[1]

[1] See note Q.

CHAPTER XII.

THE PRIMÆVAL VEGETATION.

It is now time to return from our investigation into the constitution of the great luminous centre of our system, to a consideration of the condition of our own globe at this early epoch in its history.

It has been shown to be probable that, at a very remote period in the past, after the globe had cooled down to a certain extent, its surface may have been entirely covered with water, arising from the condensation of aqueous vapour eliminated from the mass of its other component ingredients. The next stage in its history was in all likelihood the gradual breaking up of the solidified crust into great irregularities, producing vast heights and hollows—the waters being gathered into the latter, while the former, being laid bare, constituted the earliest dry-land. That this dry-land was, at an immensely remote epoch, covered with a peculiar vegetation, is evidenced by the remains of that vegetation found in the strata—chiefly those of the coal formation. The characteristics of this vegetation are such as to have led all competent investigators to the conclusion, that it flourished during many long ages, when the conditions of climate prevailing on our globe were very different from what they have been ever since the beginning of the historic period, and indeed for long before then. They show that over the entire surface of the globe, in the polar regions as well as in the equatorial, the climate must have been uniformly

moist and warm, and there is thus established a probability, that this earliest uniformity of climate depended on conditions very different from those which could have prevailed, had the globe been dependent for the distribution of its warmth on the radiation of the sun.

It has further been already mentioned that, in the opinion of those who have most thoroughly investigated the subject, the high original temperature of the globe, or rather the vibratory motion to which that temperature was due, could not have had its origin in any known natural process, and was therefore most probably excited by a power capable not only of modifying the present laws of inorganic matter, but of originating those laws. Hence it is fair to conclude that the vibratory motion in question was independent of that propagated from the sun, and preceded it in the order of time.

But it has been yet further shown that, judging from the present temperature of the globe, and the rate of its increase in descending through the strata, it is not probable that such an universal warmth of its soil, in the circumpolar as well as in the equatorial regions, as the vegetation interred in the coal formation indicates to have prevailed while it flourished, could have subsisted at a period less remote than one hundred millions of years. On the other hand, it has been pointed out in the immediately preceding chapter that, supposing the heat of the sun to have had its origin in the continuous falling in of meteoric matter during a long tract of time, that period cannot with any probability be estimated at more than eight millions of years. Doubtless if the motive energy emanating from the sun have its origin in some unknown internal cause, such as has been indicated in the preceding chapter, the period when the sun began to shine may have extended much beyond that interval. But still it would be needful to suppose, that there did

exist in the past an epoch when the sun had not begun to shine—whether eight millions of years ago, or a longer period. Looking then to the peculiar characters of the vegetation buried in the coal formation, to the difference in the conditions of climate which must have prevailed on the globe while it flourished, and to the immense remoteness of the epoch when those needful conditions were likely to have subsisted, it becomes a highly probable conclusion, that that earliest vegetation clothed the surface of the earth long before the sun had begun to shine upon our globe—being sustained by those luminous and thermal vibrations which have been shown to have probably existed as the earliest of all physical phenomena, and before the establishment of any centres of motive energy.

Assuming the accuracy of these conclusions, which are based on purely physical considerations, it becomes interesting to reflect, that by means of this earliest vegetation and by the agency of life acting through it, a large proportion of the mechanical force of those primæval undulations was converted into latent or potential energy, and thus, as it were, stored up for the use of man. This force is now doled out to us in the heat of our manufacturing furnaces, in the warmth of our domestic fires, in the light of our coal-gas and petroleum-fed flames, and in the mechanical powers of our coal-fed steam-engines. The probability is that in these we see reproduced a portion of motive energy—not, as the elder Stephenson imagined, anciently derived from the sun, but far older—resulting from that vibratory motion, which was primarily induced upon the luminiferous ether by a direct action of the vital energy of the Creator.

As regards the soil in which the earliest vegetation flourished, it appears not improbable that a large proportion of it may have been supplied by ejections of vol-

canic mud, similar to those which occur in modern times, only perhaps on a larger scale. This species of mud is known to be remarkable for its great fertility.

The chief design of the earliest vegetation of the earth appears to have been the purifying of the atmosphere, so as to fit it for animal respiration, by withdrawing from it a large portion of its carbon, which was intended to be afterwards stored up in the strata, in a mineralised condition, to furnish supplies of fuel for the human race. The actual storing up of this carbon in the strata, however, does not appear to have taken place till a subsequent period — till after the introduction of animal organisms into the world. The centralisation of light in the sun seems to have been needful to fit the earth and other similarly constituted bodies for becoming the abodes of animals. Without such centralisation, both the air and the ocean would probably have remained perfectly still—a condition which, although quite consistent with the maintenance of vegetation, is extremely unfavourable to animal life.

This consideration furnishes an additional argument in support of the conclusion, that the earliest vegetation of the earth flourished before the sun was constituted the source of its light and heat. For the earliest organisms occurring in the strata are animal. Now had the light and heat by which the first vegetation was supported been derived from the sun, its interment in the strata would have been in progress during the whole course of its subsistence. For the action of the sun would have caused the existence of rains and rivers, and the consequent wearing away of the soil on which the vegetation grew; so that large quantities of it ought to have been found embedded in the earliest sedimentary deposits. But if the first vegetation flourished before the sun began to shine upon the earth, there may have been neither

rains nor rivers during the earlier periods of its existence, consequently no wearing away of the soil on which it grew. There would simply be a succession of growths in the same soil. But as soon as the sun became the central source of the earth's light and heat, rains would begin to fall and rivers to flow, so that the plant-bearing soil would begin to be washed away, and spread upon the neighbouring shores.

Meanwhile, however, animal organisms may have begun to be produced in the oceanic depths, and to be deposited in the strata which were in the course of formation there; while it may not have been till a long subsequent period that the portions of the earth which were clothed with the first vegetation, and the shores on which its remains lay partially spread, were submerged, in consequence of some change in the level of different portions of the earth's crust produced by subterranean agency. This consideration is one of those tending to show, that the occurrence of animal organisms in the strata, before the appearance of the remains of the terrestrial vegetation, is not a decisive proof that the existence of animals preceded that of vegetables in the history of our globe.

CHAPTER XIII.

THE TEEMING WATERS.

THE appearances presented by the strata indicate that, after the source of the earth's light and heat became centralized in the sun, and the consequent formation of sedimentary deposits due to the effects of solar action, the creative processes were continued during many ages, in the course of which a vast succession of organic beings were brought into existence—the sea and the land meanwhile undergoing repeated partial changes of level, of which the general tendency was to increase the extent of the latter. The successive races of organic beings seem also to have been adapted to the varying condition of the land and water, as respects position and temperature. It is to this epoch, then, in the history of our globe, that we must assign the deposition of the strata containing organic remains, whether of plants or aquatic animals, underlying those which contain the remains of land animals.

The organic remains which first occur are those of Rhizopods, Diatoms, Sponges, and others of the more simple marine animals and plants, some of which are found even in the most ancient sedimentary deposits. They are for the most part so minute as to be discernible only under the microscope.

The Rhizopods are animals of exceedingly simple structure, being almost wholly composed of a jelly-like substance termed 'sarcode' (rudimental flesh). Notwithstanding this simplicity, they, in common with the mollusks, pos-

sess the property of clothing themselves with hard shells, composed in some cases of carbonate of lime, in other instances of pure silica. They are called Rhizopods (root-footed), because of their faculty of putting forth root-like processes, which serve the purposes of locomotion and prehension.

Of these minute animals, those whose remains occur earliest and most abundantly in the strata are the Foraminifera (Pore-bearers), so called from the pores in their shells through which the processes above mentioned are put forth, these pores being in some genera very numerous.[1]

The shells of the Foraminifera are, like those of the mollusks, mostly composed of carbonate of lime, and are found in immense profusion in the strata. Some rocks indeed, such as the oolitic limestone and the white chalk, are almost entirely composed of these shells or their fragments. The green sands of the chalk formation again are, to a great extent, composed of siliceous internal casts of the animals inhabiting the Foraminiferous shells, the shells themselves having been dissolved away. The remains found in limestone and serpentine beds belonging to the Lawrentian series of stratified rocks, which are the earliest sedimentary deposits known, belong to this tribe.

The Foraminifera are found alive at great depths in the bed of the ocean. They have been brought up by the sounding line from a depth of 2,000 fathoms in the Atlantic, and also from more moderate oceanic depths in various parts of the world. The living species, in many instances, exactly resemble the fossil. The shells of the Foraminifera being very beautiful objects, and unfamiliar except to those who devote themselves to microscopical investigations, some of the more curious and elegant of the forms

[1] For further information, see Williamson's *British Foraminifera*, and the other works therein enumerated; also Parker and Jones on *Foraminifera from the North Atlantic and Arctic oceans.*

have been represented in plate A, to which a short description is prefixed.

The fossils named Nummulites, from their resemblance to coins, belong to that class of Foraminiferous shells which are wound around a single axis, so as to form a flat spiral, the walls of the shell being tubular. They attain a much larger size than the other members of the tribe, sometimes reaching two inches in diameter, while that of other species does not exceed a hundredth of an inch. These Nummulites are so abundant as to form whole mountains, and their geographical distribution is also very wide. The stone used in building the Egyptian pyramids is almost entirely composed of Nummulites of considerable size, which by the inhabitants are termed 'Pharaoh's pence.'

The *Eozoon Canadense*, the oldest known fossil, recently discovered by Sir William Logan, has been pronounced by Dr. Dawson and Dr. Carpenter, after careful examination, to be a Nummulite of large size. Only fragments of it have yet been found. It has had a coral-like mode of growth, being composed of chambers opening one into another laterally, and superimposed in successive layers connected together by canals. The crust of the shell is tubular, like that of other Nummulites. This fossil occurs in the limestone of the Lawrentian series of rocks on the banks of the St. Lawrence, in Canada. These strata, which are nearly 30,000 feet in thickness, consist of gneiss and other quartzose, aluminous and argillaceous sedimentary deposits, and are the oldest of that class of rocks hitherto discovered. They embrace beds of limestone containing serpentine, and it is in these that the fossils are found. The lime of the fossil shell remains preserved in the limestone; but the sarcode of the animal is replaced by serpentine. This circumstance allows of the lime composing the shells being dissolved away, when a cast of the

animal in serpentine remains.[1] The Eozoon has more recently been found by Mr. W. E. Sanford in a similar formation at the Bins of Connemara, in Ireland.

A still more interesting tribe of Rhizopods are the Polycystina—so called from their being characterized by numerous cysts. They were first discovered in a fossil state in a calcareous formation in Scotland-district, in the island of Barbadoes. Specimens however have subsequently been found, along with Foraminifera, in deep-sea soundings. They are all microscopic, and remarkable for the beauty and variety of the forms presented by their shells. These, instead of being calcareous like those of the Foraminifera, consist of pure silica. The holes for the projection of the root-like processes are larger, and in general more symmetrically arranged than in the case of the Foraminifera. The Polycystina are as yet so little known to the general public, and present such a rich variety of beautiful forms, that the six plates B, C, D, E, F, G have been devoted to their illustration. Nevertheless, the species represented constitute less than the half of the whole number discovered.

One of the most remarkable characteristics of these shells is the striking resemblance which some of their forms bear to works of art—such as porcelain vases, architectural ornaments, jewelled crosses, and other articles of human design. This singular fact indicates that the human mind, in its ideas of beauty, is only a faint reflection of the divine mind, and that many of the efforts of human art are reproductions of designs previously existing in natural objects, without the artist's being at all aware of the resemblance. Similar artistic forms occur among the Foraminifera, as pointed out in the description of plate A, but they present themselves in

[1] *Quarterly Journal of the Geological Society*, February 1865.

greater profusion among the Polycystina. These and other particulars connected with this remarkable tribe are noticed more at large in the description prefixed to the plates.

The most striking circumstance, however, is the vast variety of forms assumed by the Polycystina, and their great diversity of outline, while they all have the common feature of numerous perforations, by which they are linked together into one group. Viewed as a whole, this family, notwithstanding the total absence of colour, is certainly among the most beautiful of those which the microscope has revealed to the human eye.

The Diatoms (splitters) are so called because of their tendency to split in twain.[1] Their place among organic beings has long been a subject of dispute—some regarding them as animals, others as vegetables. The latter opinion has of late years begun to prevail. According to this view, they are water-plants—the diverse species inhabiting salt, brackish and fresh waters, in all of which they greatly abound—growing either in the mud at the bottom, or supported on other plants or foreign bodies. Some species, however, grow near the surface of the water, and sink to the bottom only after death. They each consist of a single cell, composed of a membrane containing fluid, in which are certain granules. In the living state they generally contain a colouring matter of a greenish or brownish olive hue.

The cells have the remarkable property of encrusting themselves with a shell composed of pure silica, which they secrete from its solution in the water. In this particular they somewhat resemble the canes, reeds, grains and grasses, all of which coat themselves with a varnish

[1] For information regarding the Diatoms, see Prichard's *Infusoria* and Smith's *Diatomaceæ*.

of silica—as also the Corallinidæ, marine plants which encrust themselves with lime.

The cell with its siliceous crust is termed a frustule. These frustules are either solitary and free, or else attached, or otherwise aggregated together. Some species are furnished with a gelatinous cushion or stem, by which the frustules adhere one to another, and attach themselves to other plants or foreign bodies. Others have their frustules enveloped in a gelatinous medium.

It is to their siliceous shells that the diatoms owe their preservation in a fossil state, in which they are very abundant. The substances known as tripoli and bergmehl are almost entirely composed of them. They frequently form strata of considerable thickness, and they occur in all quarters of the globe and in every latitude. The greatest fossil deposit hitherto discovered is on the banks of the river Columbia in North America. At Place du Camp, that river flows between two precipices from 700 to 800 feet high. Of these cliffs the lower portion consists of a sort of clay almost entirely composed of the remains of freshwater Diatomaceæ. It attains a thickness of 500 feet, and it is covered by a layer of solid basalt about 100 feet thick, on which are super-imposed other volcanic deposits. The city of Richmond in Virginia and the neighbouring town of Petersburgh are built on a bed of diatomaceous deposits, having an average thickness of eighteen feet. In Germany similar beds, of forty feet, and some even of seventy feet in thickness, have been found. Considerable fossil deposits occur at Lough Island Reavey and Lough Mourne in Ireland, and at Dolgelly in North Wales. At Neyland in Suffolk a deposit occurs at a depth of forty feet below the present surface, and close upon the rock which forms the original bed of the estuary of the Stour. Beds of fossil diatoms have also been found in Aberdeenshire and in the Island of Mull. The shells of diatoms

likewise abound in Peruvian guano. Although it is in the more recent strata that the fossil diatoms are most numerous, yet they occur as early as in the oolitic formations, and even in some older metamorphic and porphyritic rocks; but it is a remarkable circumstance, that the fossil species are for the most part identical with those now existing, in so much that there is no well-authenticated instance of an extinct diatom. The species, however, become more numerous, and the forms more various, as we ascend from the lower to the newer formations.

In their living state, diatoms may be found wherever water has deposited mud or sediment. It is in the Antarctic Ocean, however, that the most rapid and extensive formation of diatomaceous deposits is in progress. On this point, Dr. Hooker, in his report to the British Association, 1847, says—'The waters, and especially the newly-formed ice of the whole Antarctic Ocean, between the parallels of 60° and 80° S. abound in Diatomaceæ, so numerous as to stain the sea everywhere of a pale ochreous brown—the surface having that colour as far as the eye can reach from the ship. Though particularly abundant in the icy sea, these plants are probably uniformly dispersed over the whole ocean, but being invisible from their minuteness, they can be recognised only when washed together in masses, and contrasted with some opaque substance. They were invariably found in the stomachs of Salpæ, and of other animals in all latitudes between that of the tropic, and the highest parallel attained in the Antarctic expedition. Their death and decomposition produce a submarine deposit or bank of vast dimensions—consisting mainly of their siliceous shields, intermixed with infusoria or organic matter. Its position is from the seventy-sixth to the seventy-eighth degree of south latitude, and occupies an area of 400 miles long by 120 wide. The lead sometimes sank two

feet in this pasty deposit, and an examination showed the bottom made up in great measure of species now living on the surface. This deposit may be considered as resting upon the shores of Victoria-land and of the Barriers, and hence on the submarine flanks of Mount Erebus, an active volcano 12,000 feet high. From the fact that the Diatomaceæ and other organisms enter into the formation of pumice and ashes of other volcanoes, it is perhaps not unreasonable to conjecture, that the subterranean and subaqueous forces, which keep Mount Erebus in activity may open a direct communication between this diatomaceous deposit and its volcanic fires. Moreover this bank flanks the whole length of Victoria barrier—a glacier of ice 400 miles long, whose seaward edge floats on the ocean, whilst its landward extends in one continuous sweep from the crater of Mount Erebus, and other mountains of Victoria-land, to the sea. The progressive motion of such a glacier and accumulation of snow on its surface must result in its interference with the deposit in question, which, if ever raised above the surface of the ocean, would present a stratified bed of rock, which had been subjected to the most violent disturbances.'

No inconsiderable proportion of the sedimentary deposits forming the deltas of the great rivers of the globe—such as the Ganges, the Nile, and the Mississippi, is also composed of diatomaceous shells. From these details it will be readily understood, how the shells of the Diatomaceæ should abound in the sedimentary deposits of all ages.

The siliceous shells of diatoms present a great variety of forms, some of them exceedingly beautiful. In plates H, I, J, and K, a considerable number of these forms are represented, drawn, some from fossil, others from recent specimens. Those have been selected which present the greatest diversity of outline, and are the most

remarkable for their beauty. Almost all of them are ornamented with various lines, dots, minute rings, hexagons, or other figures—rendering them objects of great interest under the microscope, whose powers they try to the uttermost—only the very finest lenses being capable of rendering some of these markings visible. The more striking of the peculiarities, which distinguish the different species, are noted in the description prefixed to the plates.

The shells of diatoms consist generally of two valves, like those of a cockle or mussel. The valves are united by their edges; but minute openings for the admission of water are left along the line of junction—sometimes continuously, in other cases partially, either along the sides or at the ends. In some species each valve consists of two very thin plates. The valves are closely applied to each other only when the specimen is young. They gradually separate in preparation for the act of splitting, and while this process is in progress, a portion of the inner membrane becomes exposed, and immediately begins to secrete fresh silica—so forming a connecting band between the two valves. This band, which is termed the connecting zone, is of a less firm consistency than the valves themselves. When the specimen is viewed by transmitted light, the band appears as a dark margin bordering the shell. It is shown separately in plate L., figs. 3, 4, 5.

One of the most interesting characteristics which distinguish the diatoms in their living state, is the power of locomotion exhibited by several of the genera. It was this faculty that led many naturalists so long to contend for their animal nature. Their movements, however, are altogether diverse in character from those of any animal. The free frustules of an elongated form move always in a straight line, first in one direction and then in the opposite,

without turning round. They never deviate from their straight course to avoid an obstacle; but if such oppose their progress, they are simply arrested, and after a pause they move straight backwards—the forward and backward movement being performed in equal times. In forms that are less elongated, the motion is more of the nature of a languid roll from side to side. This difference in the character of the motion depends on the position of the openings in the shells—the movement being caused by the water's obtaining, through these holes, access to the membrane of the frustule, which either imbibes it by endosmose, or discharges it by exosmose, the opposite points of the frustule exerting these opposite functions alternately.

But the most curious species of motion is that performed by certain genera, whose frustules grow together in long filaments, adhering side by side. In this case, the frustules accomplish their movements without separation, by sliding each along the side of its immediate neighbour. The best example of this species of motion is exhibited by the *Bacillaria paradoxa*, represented in plate L., fig. 2. Here the frustules adhere side by side, forming a long and flexible riband—there being often as many as a hundred individuals in the chain. The movement begins simultaneously at each end of the riband—the extreme frustule sliding along the edge of its immediate neighbour, till it reach nearly to its end. The second immediately begins to slide in a similar manner along the edge of the third, which straightway starts on its excursion along the edge of the fourth and so on; the movement proceeding from either extremity quite to the central frustule, which alone remains at rest. The excursion is usually in opposite directions from either extremity at the same time, but occasionally it is in the same direction at both ends. When the whole frustules on either side of the centre

have completed their excursions, so giving the riband its extreme amount of lateral extension, the motion is reversed, and continues till the riband attain a similar lateral extension in the opposite direction. The time occupied in this double excursion is about forty-five seconds. Irregularities occasionally interrupt the harmony of these movements; but they are for the most part performed in an orderly manner. If the riband be divided into two parts, each half will perform the same movements as did the whole.

In another species of the same genus, *Bacillaria cursoria*, the motion begins with the second frustule from one end, by its gliding forward along the contiguous edge of the extreme frustule, which remains at rest. The movement is successively taken up by the third, fourth, fifth, &c., which all dart forward in the same direction—each frustule gliding along the edge of its immediate neighbour, till the whole extend into a long chain, adhering together lengthwise by their corners. After the lapse of two or three seconds the movement is reversed, till the riband assume its original form, and is continued till the linear extension of the riband be resumed in an opposite direction. The rapidity and extent of the excursion increases from the terminal fixed frustule towards the other extremity; so that the frustules cross, at nearly the same moment, the line passing through the middle of the riband when in its position of repose, and thereafter dart past each other. The moving force is so considerable as to remove a somewhat bulky obstacle, and the double excursion is performed in a few seconds. If the moving end become entangled, the end previously fixed will take its place, and will in turn perform the longest excursion. This movement differs from that performed by *Bacillaria paradoxa*, only in the circumstance of the extreme frustule of the riband's forming the pivot;

whereas, in *paradoxa*, it is the central frustule which occupies that position. These motions are stimulated by light and suspended by darkness.[1]

The modes of multiplication and reproduction which prevail among the diatoms will be noticed hereafter.

Very frequently associated with the remains of rhizopods and diatoms are those of sponges.[2] Some naturalists indeed regard the greater proportion of flints as having been originally sponges, which have undergone compression, and become silicated by the action of water containing a minute quantity of silica in solution. But sponges themselves secrete silica—forming siliceous fibres and spicules; and these are what are found so abundantly intermingled with the shells of rhizopods and diatoms. Of the siliceous fibres or framework of the sponges specimens occur frequently among the Polycystina. Examples of these are given in Plate E., Nos. 86, 87, 88, and 89. The curious form No. 94 is perhaps also of sponge formation; but this is doubtful. These siliceous frames are remarkable for their artistic elegance, and their likeness to wood-carvings. Some of the spicules are also interesting because of the peculiarity of their forms, and the resemblance which some of them bear to works of art, such as crosses, arrows, picks, spears, anchors, nails, hooks,

[1] Professor Schultze, of Bonn, maintains that the movements of diatoms are due to an adhesive protoplasm lying along the exterior of the connecting membrane; the motion he attributes to undulations in this protoplasm, in virtue of which the frustule creeps along any surface to which it partially adheres. The existence of this layer of protoplasm, however, is merely inferred; for it has never been seen. This invisibility M. Schultze explains by supposing the protoplasm to be perfectly transparent, colourless, and of the same refractive power as the siliceous crust of the connecting membrane. Besides the obvious objection to this view, arising out of the invisibility of the undulatory adhesive layer, it affords no explanation of the rhythmic character of the motion—its being to and fro in equal intervals of time.

[2] For information regarding the sponges and their spicules, see Bowerbank on the Spongiadæ.

and the like; while others simulate alphabetical characters. A few examples of sponge spicules are represented in plate M. (*Frontispiece*), from which these resemblances will be at once perceived.

One of the most beautiful of all the sponges is represented in plate N., half the natural size. It is named *Euplectella speciosa*, and is a siliceous sponge found off the coasts of the Philippine Islands.

When the mind contemplates the elegance and beauty of the forms represented in the series of plates devoted to the foraminifera, the polycystina, the diatoms and the sponge-spicules, the question naturally arises—for what purpose was all this elegance of design, this elaborate ornamentation, so profusely lavished on organic structures of such extreme minuteness? It can have been of no benefit to the organisms themselves. Must we then conclude that they were thus formed simply to indulge the taste of the Divine Artist, and that they were so fabricated merely for His pleasure? Or may we not venture to conjecture that the Creator, having preordained that His intelligent creature man should, by persevering labour, possess himself of instrumental means, enabling him to subject those minute objects to the most searching scrutiny, also predetermined that he should be rewarded by discovering in those organisms manifest traces of the Creator's skill, and should be led to discern that the ideas of elegance and beauty, existing in the mind of man, are wholly derived from those which have existed from all eternity in the mind of God?

But our wonder at the beauty of these forms becomes enhanced, when we consider the extreme simplicity of the organisms which are employed as the agents for their construction. In the case of the foraminifera, the polycystina, and the sponges, the material in which the formative force seems to reside is a simple animal jelly, desti-

tute of any special organs adapted to the formation of those singular structures. In the case of the sponge-fibres and spicules in particular, it is curious to observe how the laws of crystallisation, which would, if left to themselves, determine the shapes of the siliceous secretions, are over-ruled by the formative power of the living being; so that the shapes assumed resemble works of human art, more than any of those resulting from the operation of mere inorganic laws. Yet this formative force seems to reside in a mere gelatinous varnish, covering the horny or siliceous skeleton, which constitutes the mass of what we term sponge.

Minute as are the creatures which have been under consideration, they nevertheless, from their enormous numbers, perform in nature an important function. They restore to the solid form the lime and silica dissolved by the waters of the globe. At great depths in the ocean in particular, the waters are considerably charged with these substances, and consequently possess an augmented specific gravity. But the rhizopods, diatoms, and sponges inhabiting those depths separate the lime and the silica from the water, which, thus lightened of its load, has a tendency to ascend. In this manner there is maintained, at those vast depths, a perpetual circulation in the waters, which would otherwise be in danger of remaining stagnant. The solvent powers of the water for lime and silica are at the same time restored; and these are exercised anew on the solid materials of the globe.

Although so insignificant in point of size, the organisms which have been under consideration are thus not the least important in their office; while they are among the most beautiful in their appearance, and undoubtedly the earliest of all the productions of the teeming waters.

It would at first sight appear that animal preceded vegetable remains, in the order of their deposition in the

strata. But Dr. Dawson has found in the limestone of the Lawrentian deposits, in which the *Eozoon Canadense* occurs, carbonaceous fibres and granules, which he regards as traces of decomposed sea-weeds. More recently M. A. Sismonda has reported to the Academy of Sciences his having discovered, in the fundamental gneiss of the Alps, impressions of a plant analogous to the equisetum, which is so abundant in the coal formation. This discovery indicates the existence of a shore vegetation coeval with the *Eozoon Canadense*.

M. Nordenskiöld has also reported to the Swedish Academy of Science his having discovered, in the hill of Nullaberg in Sweden, a large deposit of bituminous gneiss thirty-three mètres thick, embedded in layers of common gneiss and mica slate. The bituminous matter with which this gneiss is charged consists of carbon and carbonated hydrogen, thus indicating its organic and most probably vegetable origin.

Even were it the case, however, that the remains of rhizopods and zoophites occur in the strata before those of any land plants, such a fact would not prove that these animals existed before any terrestrial vegetation, but merely that the *destruction* of that vegetation did not begin before the existence of marine animals of the lowest type. Fragments of true coniferous woods have been found in the very lowest beds of the old red sandstone, which immediately overlies the Silurian rocks, thus showing that, after the introduction of the lowest types of marine animals, causes came into operation, by which an already existing land vegetation began to be wafted down rivers, and deposited on the bed of the ocean. But there is no proof that plants may not have grown on the dry land, for ages before the first formation of marine animal organisms. All that can be fairly inferred from the order of their occurrence in the strata, is that the circumstances

which caused the destruction of a portion of the already existing land vegetation did not begin to operate till marine animal organisms had commenced to live and die.

On one point there can be no reasonable doubt, namely, that the existence of plants must have preceded that of animals. For it is now held by the ablest physiologists, that the most characteristic difference between plants and animals is their mode of nutrition. All plants, except the Fungi and certain parasitic plants, have the power of assimilating purely inorganic materials; whereas no animal, from the lowest to the highest, possesses any such power. Their food always consists of matter already organised either by plants or by other animals. The very lowest microscopic animals feed either on the like lowest microscopic vegetables, or on other animals similar to themselves. For example, the Foraminifera feed on the Diatomaceæ, whose siliceous shells are frequently found embedded in the sarcode of the rhizopods. It is therefore obvious that the existence of the vegetable kingdom, or at least of certain members of it, must have preceded that of any member, even the very lowest, of the animal kingdom.

Much light has been thrown on the nature of the inhabitants of the oceanic depths and their mode of life, by the soundings and dredgings recently conducted by Dr. W. B. Carpenter and Dr. Wyville Thompson, in the seas northward of the British Islands. They have established the fact, that the rhizopods inhabit the bottom of the sea at the greatest depths sounded, and that there is now in course of being deposited over a large portion of the ocean's bed, a formation much resembling chalk, which, like the more ancient chalk deposits, will be, to a great extent, composed of foraminiferous shells with abundant sponge spicules. A more curious

fact has been also ascertained by those dredgings. At the distance of not many miles, there are two distinct sets of organisms inhabiting the bed of the sea—the one characteristic of a cold, the other of a much warmer temperature. This effect is produced by the set of the ocean currents. In the one case, the water at the bottom of the sea is that which has been chilled in the Arctic regions, and is flowing southward. In the other case, the water is that which has been warmed in the tropical and temperate regions, and is in its progress northwards. This fact shows the extreme caution which geologists should exercise, in judging of climatic changes by the aspect of organic remains in deposits occurring even at moderate horizontal distances.

It has been further ascertained by those soundings, that the food which is supplied to the rhizopods, sponges, and other animal organisms at those great depths, and which they assimilate by absorption, consists of disintegrated organic matter, either dissolved or suspended in the water. This fact leaves no room to doubt that the earliest progenitors of those tribes could not have existed until the oceanic waters had become impregnated with organic matter—most probably of vegetable origin, seeing the rhizopods themselves appear to have been among the earliest, if not the very earliest, animal organisms which were brought into existence.

On another point also there is quite as little room for doubt. The earliest organic remains are found embedded either in sedimentary deposits or in strata associated with such—that is to say, deposits formed at the bottom of the sea by the gradual wearing away of portions of already existing dry land. It is thus proved that the very earliest marine animal organisms did not begin to exist, or at least to be entombed in the strata, until after the dry land had appeared. But if dry land must have

thus existed before the entombment of any animal organism, land plants *may* also have existed before that event. Moreover, the existence of sedimentary deposits implies the existence of rivers; the existence of rivers implies the existence of rain, and the existence of rain implies the centralisation of light and heat in the sun. Thus we learn from the strata, that this latter event was followed by the introduction of animal life into the world. From the same source we gather that, some time after the introduction of animal life, but before the existence of land animals, the original vegetation began to be destroyed, and went to form the vast carbonaceous masses of the coal formation, which have proved so important to man. This fact also leads to the inference, that the first conditions of climate which had prevailed on the earth, and to which that first vegetation was adapted, had now ceased. We further learn, from the character of the later vegetable remains found in the strata, that the first vegetation was succeeded by a new one, suited to the altered circumstances of the globe.

The occurrence, then, of marine animal organisms in the strata before any trace of land plants in the fossil state, is nowise inconsistent with the supposition that the latter may have flourished for a long time before the first existence of animals, provided we admit (but not otherwise), that the centralisation of light in the sun may have intervened between the introduction of the terrestrial vegetation and that of the marine animals of the lowest types. There is, indeed, no absolute proof that the land-plants had this precedence, save the character of the remains of that vegetation itself. But that character, as exhibited in the coal formation, and in some of the rocks of the Silurian series, indicates, as already stated, the subsistence of a species and distribution of climate very different from those which now prevail, and so far

corroborates this view of the order of events. It has, moreover, been recently ascertained by Mr. Dawson, that in America the earliest traces of terrestrial vegetation are found in the same strata, having respect to their order of formation, as those in which they occur in Europe; thus showing the universality and simultaneousness of the operation of those causes, by which the earliest land vegetation began to be destroyed. The same conclusion follows from the universal distribution of the great coal formation over the whole globe, and the perfect similarity of the remains of the land vegetation by which the coal was formed, in every region where it occurs. The inference, deducible from that similarity, is strengthened by the circumstance, that most of the plants thus found in the coal formation, have been embedded in the place where they grew—a proof of the prevalence, at one period of the earth's history, of an uniformity of climate over its whole surface.

CHAPTER XIV.

THE LAND ANIMALS.

If there be any point which is better established than another by the evidences which the strata supply, it is that, in the introduction of organic beings into the world, there was an orderly succession, and that the inhabitants of the water preceded, in the order of time, those of the dry land. It is further manifest from those evidences, that in each of these two great divisions of the animal kingdom there was also a succession, in general from lower to higher, in the order of their appearance. This is more particularly true of the land animals, the remains of whose highest orders never occur save in the newer strata; while it is only in the most recent of geological deposits that there have hitherto been found any traces of man.

It is thus rendered indisputable, that all terrestrial organisms whatever must have had a beginning, and that the beginning of the several classes and orders must have been not simultaneous but successive. This conclusion naturally leads to a consideration of the important question of the origin of organic genera and species—a question which has awakened much attention in recent times.

Ere proceeding to enter on this interesting topic, however, it is needful to present a brief summary of the facts on which any theory whatever relating to the origin of organic genera and species must be based.

Without knowing something of the manner in which organisms are formed now, it is impossible to acquire even the most remote idea of what may have been their mode of origination, when they first began to be.

The phenomena, to which a preliminary examination must thus be given, are these ten :—1st, Apparent Organic Origination. 2nd, Organic Multiplication. 3rd, Generation. 4th, Primary Development. 5th, Metamorphosis. 6th, Fertile Nurse Forms and Parthenogenesis. 7th, Parasitic Life. 8th, Specific Variation. 9th, Hybridation; and 10th, Latent Life.

Those who wish to study these subjects more thoroughly will do well to consult Mr. Rymer Jones' 'Outline of the Animal Kingdom,' 'The Metamorphoses of Man and the Lower Animals,' by M. Quatrefages, Darwin's 'Origin of Species,' Henfrey's 'Elementary Course of Botany,' and the works of Professors Owen and Huxley, Dr. Carpenter, &c. All that can be attempted here is such a mere outline as may suffice for the comprehension of the general argument. For the sake of brevity, only the facts shall be stated; the authorities by which they are authenticated will be found in the works to which reference has been made.

CHAPTER XV.

APPARENT ORGANIC ORIGINATION.

Various attempts have from time to time been made, to ascertain whether or not there may be such a thing in nature as organic origination, termed also spontaneous generation—that is, the actual origination of organic beings from inorganic materials, brought into conjunction in certain proportions, and aided by the stimulating energies of light, heat, or electricity. Some of these attempts have been attended with apparent, but none of them with unquestioned, success. Indeed, the difficulties attending this class of experiments are so formidable, that little confidence can be placed in the results which may be attained.

All water, and, continually floating in its lower strata, even the atmosphere itself, contains, in large quantity, the rudiments of organisms capable of further development. It has also been experimentally proved, that all surfaces, solid or liquid, exert a power of attracting to themselves a highly compressed film of atmospheric air, which it is difficult to remove. Even after the removal of this film, the exposed surface, immediately on its being brought into contact with the atmosphere, recommences the formation of another. Hence it appears that the very vessels employed, or the materials used, may have adhering to their surfaces a film of air containing the already formed rudiments of organic bodies, which will instantly begin to multiply and become developed into

organisms, in any fluid which may be made the subject of experiment. It will thus be perceived to be extremely difficult to determine whether the organisms, thought to be obtained in such experiments, may not have already existed in a rudimentary state, and merely found a conjunction of circumstances favourable to their development, in the materials which the experimenter may have employed.

In all cases where apparent success has attended the experiments, there has either been free access of atmospheric air, or else there has been present some small portion of already organised matter. This last, though apparently lifeless, may yet contain germs which possess latent life, and which even the heat of boiling water may not be able to deprive of all power of vitality; for it has been experimentally found, that some of the lower forms of living organisms, or their germs, are capable of withstanding this high temperature.

One of the most remarkable cases of apparent organic origination was that of the electric mites, obtained by Mr. Crosse during the prolonged action of his large galvanic batteries charged with water only.[1] The mites did not make their appearance till after the battery had been kept in action for several weeks or even months, during which various fluids were being subjected to electrolysis. There is no probability of these creatures having resulted from an electrically effected combination of inorganic materials. In the first case in which they were discovered, they made their appearance on a piece of porous red oxide of iron, which was placed between the poles of the battery, and kept constantly moist by a solution of soluble glass. In the other cases they appeared on the wires forming the poles, or about the terminal cells

[1] Noad's Manual of Electricity; § 511, 512.

of the battery. The probability is that, in all these instances, the impregnated eggs of the mites were precipitated from the atmosphere mixed with fine dust; that the electricity merely favoured the hatching of the eggs, and that the dust supplied food for the further development of the animals.

Mites were also found by Sir David Brewster in a situation not less extraordinary; namely, between the films of mica in optical contact. Although it is possible that these mites may have insinuated themselves between the plates of the mica after it was formed, the probability seems greater, that they have been embedded in the mineral while it was in the course of formation, consequently that these are in reality fossil mites.[1]

Of experiments made with the direct object of ascertaining whether organisms are ever in any case produced from inanimate materials, the most important are those of Messrs. Pouchet, Joly, and Musset; of Dr. Child, Oxford, and of Dr. Jeffries Wyman, Boston, U.S., whose results agree on the positive side; and those of M. Pasteur, Messrs. Schultze and Schwann, M. Schroeder, M. Balbiani, and Mr. Samuelson, whose results agree on the negative side.

The mode of procedure, adopted by the three experimenters first above-named, was to introduce air through distilled water into a close vessel, so that the air might rest on the surface of the water—all other air and all other materials being excluded. The air was obtained from various sources—from towns, mountain tops, subterranean vaults, &c. On being examined at the end of eight days, the distilled water was, in all these cases, found free from any traces of organic life, of germs or eggs. On the other hand, if a minute quantity of fermentable material

[1] See *Transactions of Royal Society of Edin.*, xxiii. 95.

was introduced into the distilled water, and it was simply sheltered by a bell glass, when examined at the end of eight days, the water was found to contain myriads of animalcules. By the first experiment they sought to establish, that the air is not the source whence the eggs or germs of the animalcules are derived; and by the second, that these eggs or germs absolutely have their origin in the ferment.[1]

Both of these experiments, however, are inconclusive. Infusoria multiply so rapidly, that a very few eggs or germs falling into water would, at the end of eight days, amount to myriads. But Infusoria, like all other animals, require appropriate food, without which they will neither grow nor multiply. In pure distilled water this food was wholly absent, so that any eggs or germs, which may have fallen from the air into the water, and been hatched or developed on the first day, would, for want of food, neither grow nor multiply, but speedily perish. Their bodies would become decomposed, and being small in number, they would leave no trace behind. The first experiment therefore proves, not that the air contained neither eggs nor germs, but only that pure distilled water is insufficient to sustain life in the animalcules proceeding from them. In like manner, the second experiment fails to prove the eggs and germs to have had their origin in the ferment; because it is equally probable that they fell from the air, and, on being hatched in the water, found, in the ferment which it contained, an ample supply of nourishment to maintain their growth and promote their multiplication.

Dr. Child enclosed milk, or fragments of meat and water,

[1] M. Pouchet affirms that, in the course of his experiments, he ascertained that the nature of the light, to which solutions are exposed, has a sensible effect on the nature of the organisms developed. The light which promotes the development of animal organisms stands in the order—white, red, violet, blue, green; while, for vegetable organisms, the order is green, blue, violet, white,—the red being prejudicial.—*Hétérogénie* (1859), p. 197.

in small glass globes. Into some of these globes he introduced air, previously passed through a porcelain tube containing fragments of pumice heated to vivid redness. Into others he introduced respectively oxygen, hydrogen, nitrogen, and carbonic acid gases. In several instances he heated the bulbs with their contents up to the boiling point, during periods varying from five to twenty minutes. The bulbs were then hermetically sealed, and after the lapse of various times—from three to four months—the contents were examined under the microscope. Organisms were found in all the bulbs which had not been subjected to boiling. Among those which had been boiled, the bulbs charged with hydrogen and carbonic acid gases exhibited no signs of life. In those charged with oxygen and heated atmospheric air organisms were found. In those charged with nitrogen organisms were discovered only in the bulbs containing meat and water—not in those containing milk.

Schultze and Schwann passed atmospheric air through sulphuric acid and caustic potash, before allowing it to play on the infusion of fermentable substance, and at the end of two months found no signs of life, while similar infusions exposed to common air teemed.

Schroeder filtered the air through cotton wool, and found that, when infusions were first boiled and then exposed to this filtered air, no living organisms were developed. On repeating this experiment, Mr. Samuelson found that filtering the air through cotton wool only diminished the number and variety of the organisms, but did not wholly prevent their development. This difference of result might be due to a difference in the bulk and degree of compression of the wool, through which the air was sifted.

M. Pasteur enclosed a fermentable liquid in flasks with long necks, leaving about two-thirds of the space in each

flask empty. The contents were then boiled, and the necks drawn out and sealed during the ebullition. By breaking the necks in different localities, he allowed the air to enter with violence, carrying with it whatever it might have held in suspension. The flasks were immediately resealed, and kept in stoves heated to between 70° and 80° F.—the temperature best adapted to the development of Infusoria. In a few days the liquid in most cases showed signs of decomposition, and, on examination under the microscope, the several flasks exhibited organisms of the most varied kinds—greatly more various than had the flasks been exposed to the common air of a single locality. On the other hand, in several of the flasks, the liquid remained absolutely unaffected, and showed no signs of life whatever. M. Pasteur hence infers, that it is possible to find, in certain localities, air quite free from germs, but that in general such germs are widely diffused throughout the atmosphere, varying in different places. He also tried several methods of intercepting the germs on their passage into the flasks, and thus succeeded in preventing the development of life. Mr. Jeffries Wyman's experiments and results agree with those of Dr. Child. He also tried the methods followed by Schultze and Pasteur, for arresting or destroying the germs in the air on its passage, but he affirms with opposite results from theirs—averring that he found organisms in cases and circumstances where they found none. Mr. Samuelson and M. Balbiani operated with a variety of fermentable substances dissolved in distilled water, without obtaining much variety in the organisms, and exactly similar kinds were obtained by introducing into the distilled water the common dust falling from the air, first allowing it to fall on glass, and then washing it off with distilled water into a vessel containing that liquid. The warmer the atmosphere, the more abundant and varied were the

organisms obtained, from simply allowing the air to deposit into distilled water what it held in suspension. Mr. Samuelson then tried dust taken from rags brought from various quarters of the world, shaking it into distilled water. He thus obtained several organisms differing widely from those developed, when the dust from the air of this country was employed.

More recently this field of research has been entered by Professors Lister and Tyndall on the one side, and Dr. Bastian on the other. Mr. Lister has shown that, in the case of pus drawn from an abscess, the first portion is always fresh, and free from microscopic organisms, but that, when there is a subsequent accumulation of pus after the instrument has been introduced, this second quantity is sometimes putrescent and abounding in microscopic organisms, which he traces to germs derived from the air, and introduced into the abscess by the instrument—such being their only conceivable source. In the case of an internal abscess, on the other hand, where the air which may have obtained access to it has first been respired, no such effect is produced, because the air is freed from its germs by respiration. This fact was confirmed by Professor Tyndall, who, by passing a beam of light through respired air, demonstrated optically, that it is entirely deprived of anything capable of reflecting the smallest quantity of light, in this respect differing much from common air, which abounds in reflective particles.

Professor Lister also repeated some of Pasteur's experiments. He boiled a highly putrescible liquid in flasks with very long narrow necks, one of which had its neck left straight and upright, while the others had their necks bent several times at a sharp angle and placed horizontally. All the necks were left open to admit free access of atmospheric air. Only in the vessel with the straight

upright neck was there any putrescence or development of organisms. The others remained free from such, and with their contents unchanged for many months. But when the liquid they contained was made to flow backwards, so as to sweep into the vessel any dust or germs that might have collected in the sharp angles of the neck, the speedy result was putrescence with development of organisms.

On the other hand, Dr. Bastian avers that, in concert with Professor Frankland, he has made a series of experiments with solutions contained in airless and hermetically sealed flasks, which had been previously subjected to a temperature of 148° to 152° C. This high temperature, however, is the only peculiarity of these experiments, and it falls far short of demonstration; for living organisms have been known to withstand a temperature much above what is sufficient to disintegrate and decompose organic tissues in the absence of life. In some recent experiments made by Mr. Staniland Wake on milk, he boiled a quantity of that liquid in a covered saucepan, until it had become quite desiccated and partially charred. Having scraped off some of this matter from the bottom of the pan, he placed it in distilled water, and, at the end of a week, it teemed with organisms, among which were Amœbæ, whose germs must have been derived from the milk, having withstood the temperature that sufficed to char a portion of that liquid.[1] The feat of M. Chaubert, who remained in a hot oven, until he cooked a beafsteak by the same heat to which he was himself exposed, illustrates the same fact. So does also the earlier case of Sir Charles Blagden and others, who remained a considerable time in a room heated up to 260° F., which sufficed to make their watch-chains singe their clothes; yet they felt no incon-

[1] Scientific Opinion, iii. 540.

venience. It has also been experimentally proved, that the human hand, if simply moistened, may be plunged into molten iron without sustaining injury. The truth is, that it has not yet been thoroughly ascertained what is the extreme amount of heat to which a living organism may be exposed, particularly while in the encysted condition, without destruction of life. A temperature which would prove destructive to some, will be easily withstood by others.

From the entire series of these experiments may be deduced the following conclusions :—

1. Throughout the lower strata of air in the atmosphere in its ordinary state, there are widely diffused the eggs and germs of minute organisms, varying with the locality and season of the year.

2. Samples of air may nevertheless be occasionally found quite destitute of such eggs or germs.

3. In order to the development, growth, and multiplication of the organisms proceeding from these eggs or germs, it is needful that they fall into water containing some fermentable substance, or some already organised materials, which may serve as food; but the ordinary dust suspended in the atmosphere is sufficient for this purpose.

4. The eggs, or germs, contained in the air may be either destroyed or arrested in their passage, by subjecting the air to a very high temperature, or by passing it through sulphuric acid and caustic potash, or by sifting it through a considerable mass of cotton-wool, and under these circumstances the development of living organisms is prevented.

5. Even where the air has been thus deprived of its eggs and germs, before being brought into contact with the water, it nevertheless occasionally happens that living organisms are developed; but in all such cases the water

contains an already organised material, which has been exposed to the atmosphere before being introduced into the water, and has thus had an opportunity of receiving eggs or germs from the air.

6. The eggs or germs of the Infusoria are not deprived of their vitality by being subjected to the temperature of boiling water. This fact will occasion less surprise, when it is remembered that the Rotatoria, while in the encysted state, may be revived after exposure to a temperature even exceeding that of boiling water, provided the heat be not too suddenly applied. The effect of boiling is simply to expel the oxygen combined with the water which, if left undisturbed, suffices to keep alive the Infusoria, independently of the character of the gas, which may be superincumbent on the surface. If that oxygen, or an equivalent quantity, be not again absorbed by the water, the Infusoria will perish.

It will be perceived that all the experiments fall far short of proving living organisms to have been produced by the combination of purely inorganic materials, aided by the stimulus of light, heat, and electricity. In every case there was either free access of air, whence eggs or germs might have been derived; or else there was an already organised material in which such eggs or germs might have been lurking. It is not even necessary to suppose these eggs or germs to have fallen from the air upon those organised materials, immediately before their introduction into the water. For, it being proved that the air of the atmosphere, in its ordinary state, contains multitudes of those eggs or germs diffused throughout its lower strata, it follows that, in the processes both of animal and vegetable respiration, those eggs or germs must enter the respiratory system of living organisms, and thence pass into their circulation and become deposited in their tissues. The fact noticed by Professors Lister and Tyndall, that air expired from the lungs is absolutely free

from any trace of dust or germs, shows that the germs contained in the inspired air have all been absorbed into the organic system. Similar germs may also enter the higher organisms through the medium of their food—especially their drink, or even by external contact with the skin, passing through its pores; and such germs may become rapidly developed, producing diverse zymotic and other forms of disease. More generally, however, they lie dormant, until roused into activity by circumstances favourable to their development, such as the death of the organism in whose tissues they lurk, and the free access of air and moisture, resulting in the phenomena of putrefaction. In none of the experiments which have been recorded, in which living organisms were obtained, was the possibility excluded of the presence of eggs or germs, introduced by one or other of the modes above noticed.

No experiments made with matter which has been already organised will ever suffice to establish artificial organic origination. Let a chemist take perfectly pure carbonic acid gas and perfectly pure ammoniacal gas, neither of which has been ever exposed to the atmosphere, and let these be forced into distilled water in a close vessel, to which in like manner the air of the atmosphere has had no access; when, by the aid of light, heat, electricity, or magnetism, prolonged for any length of time, there shall have been produced in this solution living organisms, animal or vegetable, it will then be soon enough to believe in the artificial manufacture of life.

Until that feat shall have been accomplished, we must be content to make any approach, which may be possible, towards a knowledge of the manner in which organic bodies may have had their origin, by studying the phenomena exhibited in their multiplication and reproduction from already existing organisms.

CHAPTER XVI.

ORGANIC MULTIPLICATION.

There are three principal modes in which individual organisms multiply themselves. 1st. Cell-multiplication; 2nd. Fission; 3rd. Gemmation.

Cell-multiplication is frequent among the lower classes both of animals and vegetables. An organic cell consists essentially of a membranous envelope enclosing a fluid, in which is usually contained a minute body termed a nucleus, which again contains another still more minute, called a nucleolus. The envelope is generally double, consisting of an outer membrane termed the cell-wall, and a ductile lining to that membrane composed of a dense mucilaginous substance, and called the primordial utricle. The multiplication of cells is effected in four diverse ways. First, the cell becomes divided into two by a constriction or partition formed in the middle. The two halves separate, become independent cells, and repeat the process of self-division. Second, instead of one constriction or partition there may be several; so that the self-division proceeds simultaneously in several directions. Sometimes, in this case, the new cells do not actually separate one from another, but continue adherent so as to form a cellular mass. Third, the new cell may protrude outwardly from the cell-wall of the old one, and, after attaining a certain size, become separated from it. Fourth, two new cells may be formed within the old one, and, on attaining maturity, burst its envelope, and

issue forth as independent cells destined to repeat the process. The most important function in cell-multiplication is performed by the primordial utricle, which, preparatory to the formation of the new cell or cells, becomes more or less separated from the cell-wall, and doubled in upon itself. It then partially or wholly clothes itself externally with a new cell-wall, which intervenes between it and the old one, and thus severs the cell contents. When the cell ceases to multiply itself, the primordial utricle becomes absorbed.

Cell-multiplication prevails among the diatoms, and it proceeds so rapidly that, from a single frustule, there may be produced hundreds of millions in a month. In preparation for this process the valves of the frustule gradually separate, and the connecting zone is formed between their edges. Then the primordial utricle folds in upon itself, inside of the connecting zone, until its doubling reaches quite to the centre of the cell. Each fold of the utricle thus formed rapidly acquires a new membranous cell-wall, with an external coating of silica; and, when this has been completed, the connecting zone drops off, and the two new frustules, into which the original one has thus become divided, separate from each other, and ere long repeat the process. A frustule undergoing division in this manner is represented in Plate L., fig. 6, taken from Smith's 'Diatomaceæ.' It will be perceived that, in this case, each of the new frustules has a new valve and an old one, the latter being one of those of the parent frustule. It is only in the free species of diatoms that the separation of the two new frustules is complete. In many genera they remain attached, forming long chains or groups like those represented in Plate K. In others, the act of division is accompanied by an abundant secretion of mucus, which envelops the frustules, and by its persistence produces

the aggregated species. These last approach in character to vegetable tissue, only each individual cell retains an independent vitality more decided than is that exhibited by the cells of which tissue consists.

In certain species, among others those represented in figures 19, 36, 40, 43, 87, 88, 89, instead of the primary frustules dividing into two, a pair of new frustules are formed within the old one, which, as the new enlarge, bursts and falls off. In this case the connecting zone, at first merely a well-marked line, increases in breadth until the new frustules are fully formed. It thus sometimes attains an extravagant development, extending beyond the edges of the valves. It has also in several species an unusual persistence, holding the two frustules together after division.

There are certain species in which it occasionally happens that, instead of a pair, there is only one frustule formed within the old one. This sometimes occurs several times in succession, giving rise to a compound frustule, consisting of the parent cell and a number of enclosed cells, each embraced by the valves of the one in which it was formed.

It is by cell-multiplication that all the tissues of organic bodies in the vegetable kingdom are produced; and the same may be affirmed, to a certain extent, with respect to animal tissues. But there are entire animals, which consist of nothing but the simple, jelly-like substance termed sarcode; while, in this same substance, many animal organs and tissues have their origin. Nor do the animals, their tissues or organs, either consisting of sarcode or formed from it, constitute the only exception in the animal kingdom to that generality of cell-formation which characterizes the vegetable world. There are other phenomena presented by the lower animal organisms—more especially the formation of internal void spaces, and the develop-

ment of organs within these, showing that their tissues and organs are sometimes developed otherwise than by cell-growth and multiplication.

Fission, the second principal mode by which an organism may multiply itself, prevails among the lower types of organic nature. It is of two sorts — irregular and regular. In animals consisting wholly of sarcode, that substance is so entirely pervaded by life and its accompanying formative power, that any portion of the sarcode, which may become detached from the main body, is capable of growth and development into a perfect animal of the same sort as that from which it was severed. Examples of this occur among the Amœbæ, the Rhizopods, and the Spongiadæ. Such detachments of portions of the sarcode appear to take place sometimes spontaneously, sometimes by external violence. Even in those animals in which the tissue has advanced considerably beyond the stage of simple sarcode, such as the polyps, portions violently detached from the main body will grow, and become developed into perfect animals of their kind. In these cases the fission is irregular.

Regular fission, again, is of two sorts—duplex and complex. In duplex fission the organism becomes divided into two exactly similar, much in the manner of simple cell-division. It may take place in one of three directions, longitudinally, transversely, or obliquely. In all three cases certain portions of the primary individual have to be reformed, in order to constitute the two new individuals; but each of these retains in its constitution a portion of the parent. When the fission is longitudinal, there is required the least amount of this formation of new parts. In animals having a head, a trunk, and a tail, each of these divides and acquires a new half. But where the fission is either transverse or oblique, one of the divisions has to form an entire new head, and the other an entire

new tail, while each has to form anew certain parts of the trunk. This process is performed with great rapidity, and is repeated many times in succession.

In complex fission the individual divides into more than two, usually into some multiple of that number. This process is frequently preceded by a preliminary step, that of encysting. The organism secretes a sort of mucus, which gradually hardens and encloses it as in a cyst. Sometimes also the organism encysts itself for the mere purpose of its individual preservation against the effects of cold, dryness, or other influences adverse to its welfare. In that case it remains torpid; and, when the adverse circumstances cease to operate, the envelope is thrown off and the organism regains its freedom.

Complex fission takes place sometimes by successive stages, sometimes all at once. The latter mode occurs chiefly among animals consisting wholly of sarcode, and is generally preceded by encystment. The entire mass of sarcode breaks up into a multitude of germs, which, on the rupture of the cyst, escape and commence an independent existence. When complex fission occurs by stages, it presents two varieties. In the first, the stages are few, seldom exceeding four or five. The organism first undergoes duplex fission, the two, thus produced from one, remaining within a common envelope, but each forming a separate envelope for itself. Then each of these two likewise undergoes duplex fission, so producing four, each of which forms a separate envelope, while all remain within the common integument. This process is repeated again and again, producing first eight, then sixteen. Lastly, the outer covering bursts, and the enclosed organisms escape, to recommence the same cycle of changes.

The second variety of this process in like manner starts with a duplex fission, the two individuals remaining with-

in a common envelope, but in a state of freedom and mobility, without either of them forming each a separate envelope for itself, as in the former case. The fission is repeated a great many times in succession, until the numbers produced amount frequently to several hundreds. The common envelope meanwhile enlarges to admit of this increase, and the organisms move about within it in a rapid and irregular manner. Eventually they escape by the rupture of the envelope, and each as an independent being repeats the same process. The new organisms are generally smaller in this than in the former case.

The third sort of individual multiplication is gemmation, which is either external or internal. The external presents two varieties. In the one, the buds produced continue adhering to the parent, unless forcibly detached. In the other, they separate themselves from the parent and become developed independently. In this latter case, the products of gemmation are termed bulbs. These two varieties occur both in the vegetable and animal kingdoms, but are confined to the lower members of the latter. Among plants there are two sorts of adhering buds—the leaf-buds and the flower-buds—the latter containing the sexual organs. Among animals, some of the polyps present examples of buds adhering to the parent. In the vegetable kingdom there are several sort of bulbs. 1st. Simple bulbs, like those of the tulip and the hyacinth. 2nd. Tubers with eyes, like those of the potato and the dahlia, in which the eyes are the true germs. 3rd. Simple cells termed *conidia*, which are produced by some of the lower forms of the Fungi, besides others resulting from internal gemmation to be presently noticed.

Among some of the Protozoa in the animal kingdom, wart-like excrescences form on the outer integuments, and after attaining at the expense of the parent a certain

stage of maturity, they detach themselves and assume an independent existence. Certain of the Hydriform Polyps also, as Coryne and Tubularia, besides producing buds similar to those of the common Hydra, which remain for a considerable time attached to the stem, produce others which, when mature, separate themselves from the parent, and are therefore of the nature of bulbs. In Tubularia, these bulbs grow upon small footstalks within the lower circle of the tentacles, and at maturity detach themselves and swim about freely.

This process differs from fission, in which certain of the organs of the parent are divided between the two resulting organisms; for in gemmation the whole of the organs of the new individual are formed from the foundation, while those of the parent remain intact.

Internal gemmation likewise occurs both in the vegetable and animal kingdoms. The new individuals are formed in the interior of the parent, from which they become detached on attaining a certain stage of maturity, so that they are of the nature of bulbs.

Among plants, examples of internal gemmation are furnished by the Lichens and Algæ. In the Lichens, the gemmation takes place in the soft internal layers of the thallus or body of the plant, where are produced green cells, named *gonidia*, which escape by breaking through the integuments of the thallus, and immediately commence a separate and independent growth. Among the Algæ, in the orders Dictyotaceæ and Rhodospermeæ, the gemmation occurs in small lobules formed in the thallus. The products contained in these lobules are minute parent-cells, divided into four chambers, and thence called *tetraspores*. These escape by rupture of the lobule, and each begins forthwith to grow as an independent plant. In the Confervoid Algæ, gemmation may take place in any individual cell of the plant; but in the Phæosporeæ

it is confined to definite parts of the thallus. The bulbs produced in both of these orders of Algæ are corpuscles or cells, furnished with vibratile cilia, in virtue of which they move freely in the water—their movements being apparently spontaneous. From this circumstance they are termed *zoospores*. They are formed by the conversion into distinct corpuscles of the cell contents of individual cells, whence they escape by rupture. After moving about for a while, they become encysted, and they are subsequently, by cell growth and multiplication, developed into plants like those from which they spring.

In the animal kingdom, internal gemmation occurs not only among some of the protozoa, but even among some of the insect tribes. Examples will be given hereafter.

CHAPTER XVII.

GENERATION.

GENERATION is either unsexual or sexual. In the former case a union takes place between two individuals which are not distinguishable the one from the other in their external appearance, their internal structure, or in the materials supplied by each to the combination. The union is permanent, and the uniting organisms contribute the whole of their substance to form the progeny. This process is termed conjugation, and is found among the lower orders both of animals and plants. It generally occurs among those organisms which have the power of individual multiplication. The Diatoms, the Desmids, and the lower Algæ furnish examples in the vegetable, and certain of the Protozoa in the animal kingdom.

In the case of the Diatoms, the phenomena presented vary according to the stage in which the process of cell multiplication may be found, at the moment when conjugation begins; for cell multiplication continues during the entire life of the organism, and is not suspended by conjugation.

If two frustules conjugate at the moment when the process of cell division is in its earliest stage, and before separation of the cell contents of each has been effected, the result will be the production of a single sporangium, or spore-frustule, formed by the union of the cell contents of both the parent frustules, which the sporangium greatly exceeds in size.

If, at the moment of conjugation, the process of cell division has proceeded a stage further, and the cell contents of each frustule have to a certain extent become segregated, preparatory to the final division, conjugation ensues between the segregated contents of each frustule; so that two sporangia result from the union.

When the process of cell division has advanced to the stage of the complete formation of the two new frustules, with the exception of the two new siliceous valves, conjugation may take place between the two immature frustules, within the valves of the original frustule. There results a single sporangium from the combination of the cell contents of these two freshly formed frustules. This modification gives rise to the appearance of there being only a single frustule engaged in the production of the sporangium.

There is yet a fourth modification of the circumstances under which conjugation may occur. When the union is formed between two immature frustules within the valves of the parent, these two immature frustules may begin to undergo division while the conjugation is in progress, so that instead of one, there are two sporangia formed between the parental valves. This mode produces the appearance of two sporangia emanating from a single frustule.

When conjugation takes place between two mature frustules, each usually puts forth one or else two processes, according as one or two sporangia are to result. These processes unite to form a tube, through which the cell contents of the two frustules intermingle; and these tubes ultimately become the sporangia. While the conjugation is in progress, there is an abundant secretion of mucus, which envelopes both the conjugating frustules and the sporangia. In plate L, fig. 1, taken from 'Smith's Diatomaceæ,' two frustules are represented in the act of conjuga-

tion—the four small valves being those of the parental frustules in a state of separation, the large valves being those of the two resulting sporangia, and closed. In some species the sporangia lie along, in others athwart the empty valves of the conjugating frustules.

In some of the chained species it is only the terminal pair that conjugate; while in others the conjugation takes place throughout various parts of the chain, so that the ordinary frustules and the sporangia continue to form links in the chain, till the latter become ruptured. An example of these two sorts of frustules, forming parts of the same chain, is represented in pl. K. fig. 100.

In some cases cell division occurs even in the sporangium, so that a single sporangium may thus multiply itself into several others of the same size and appearance. But this multiplication does not appear to be carried to any great extent. In most cases the sporangia cease to grow or divide after their first formation. They remain for a length of time in a still condition, during which the cell contents become broken up into a multitude of germs or spores. After these have attained a certain stage of maturity, the valves of the sporangium separate, and the young brood issue forth. Each young individual grows rapidly, and on attaining maturity begins to multiply itself by cell division, and to repeat the same cycle of changes as was performed by its parents.

Of conjugation in the animal kingdom, an example is furnished by the Gregarinida, a group of protozoa. They are parasitical animals found in the intestines of worms, mollusks, insects, and other tribes of the invertebrata. They are so simple in their structure that they may be compared to a mere cell, or to the ovum of the higher animals. They are composed of a homogeneous matter resembling albumen, with numerous coarser and finer granules and fat-like globules, and they are enveloped in

a more or less firm membrane corresponding to a cell wall. They have always a central vesicle containing one or more granules, answering to the nucleus of a cell. Of these parts, the general mass may be compared to the yoke, and the nucleus to the germinal vesicle of an ovum.

These organisms, while conjugating, encyst themselves. The two Gregarinæ approach till they come into contact, when by mutual pressure they so flatten their adhering surfaces, that the pair assume a globular form. There is, meanwhile, secreted a soft gelatinous substance, which completely envelopes the conjugating pair, and which, by gradually thickening, hardens into a membranous cyst. The enclosed Gregarinæ after a while break up into numerous germs, which escape on the bursting of the membrane. These germs are spindle-shaped, and consist of a somewhat firm wall, enclosing a finely granular gelatinous substance. After a time the wall is ruptured, and the gelatinous contents assume the aspect of an amæba, consisting entirely of sarcode. The organism then grows, acquires a more globular shape, forms a new investing membrane, and becomes exactly like the parental Gregarinæ whence it sprung.

The conjugation in this case differs somewhat from the process followed by the Diatoms, for in them there is an actual intermixture and combination of the cell contents of the conjugating frustules; whereas in the Gregarinida no such intermixture can be traced. Their mode of generation therefore constitutes an intermediate link between conjugation, as it exists among the Diatoms, and individual multiplication by encystment, and the breaking up of the entire organism into germs, which occurs among some of the other protozoa. From this latter case, the process followed by the Gregarinida differs principally in their being encysted, not individually, but by pairs.

In sexual generation, the offspring is formed by the

conjunction of two different elements, the sperm and the germ, which are, for the most part, furnished by separate and diverse organs, specially appropriated for the purpose. These organs are situated sometimes in one and the same individual, as in monæcious plants and hermaphrodite animals, sometimes in two separate and diverse individuals, as in diæceous plants, and all animals having separate sexes.

The sperm and germ elements are both exceedingly minute, and can be discerned only under the higher powers of the microscope. They vary little in form and appearance. In animals the sperm element is usually thread-shaped, with a small bulb at the one end and tapering to a point at the other. They always occur assembled in great numbers, and are most commonly immersed in a fluid. They are also generally endowed with energetic powers of locomotion, and are hence called *spermatozoa.*

In plants, the sperm element presents a greater variety. There have been recognised three distinct sorts. The first are rod-like bodies termed *spermatia*, found in the Fungi and Lichens; but their true spermatic character has not been quite clearly established. The second sort are bodies furnished with two or more vibratile cilia, which serve them as instruments of locomotion, so giving them the aspect of animalcules, whence they are termed *spermatozoids.* Among the Algæ they are generally spindle shaped; among the Characeæ, the Liverworts, the Mosses, the Ferns and Horsetails, they are spiral. In the two last named tribes the vibratile cilia are numerous. The third sort prevails among the Phanerogamia or flowering plants, and is termed *Pollen.* It consists of a membranous cell enclosing a fluid named the *Fovilla*, containing starch granules and oily globules.

The pollen of plants constitutes an interesting series of microscopical objects, several of which are represented in

plate O, to which is prefixed a description indicating the peculiarities of the different forms. If the whole series be carefully examined, it will be perceived that several of the forms are transitional. The sphere is evidently the fundamental form, the departures from which take place by gradations; so that the whole are linked together by certain bonds of connection. There is here a striking analogy to the phenomena presented by crystallisation, the whole forms assumed by pollen being as easily traceable to the sphere, as are the various crystals of the tessular system to the cube.

Pollen is very persistent. When dried it may be preserved for an indefinite period, and on being wetted it will recover its original size and form. No. 38 was drawn from a specimen which had been preserved in a herbarium for nearly a century. Even the fertilizing power of pollen subsists for a considerable time. M. Belhomme has found that the pollen of Dicotyledonous plants remains fertile for periods varying from one to three years—that of Monocotyledonous plants for six years.

A remarkable circumstance connected with pollen is the change of form which it undergoes preparatory to the performance of its special function. Immediately on its touching the vesicle containing the germ element, the pollen cell puts forth one or more tubular projections, so as to come into close contact with the germ cell, and facilitate the intermixture of the contents of the two cells. In certain plants, in which the pollen tube has to reach the germ cell by a long and somewhat circuitous route, as in the case of the *Tigridia conchiflora*, one of the Iris tribe, the tube appears to extend itself by cell-growth during its passage, being nourished by juices supplied by the style which it traverses. In other cases, as among most of the Orchids, the anthers containing the

pollen grains are so situated in relation to the ovule containing the germ cell, as to render necessary the intervention of insects, in order to bring the pollen into contact with the ovule.

In *Dombeya angulata* again the access of the pollen to the ovule is secured by supernumerary long barren stamens, which first bend down to receive the pollen from the anthers, and then erect themselves to lay it on the stigma.

It is uncertain what is the precise manner in which the fovilla of the pollen tube enters the germ cell. The extension of the pollen tube is analogous to what occurs in the conjugation of certain genera of the Diatoms, whose frustules each put forth one or two tubular processes, by means of which the conjugation is effected, and the cell contents of the frustules are commingled. Indeed there is a striking resemblance between pollen and the Diatoms, Desmids and other unicellular plants, belonging to the class Protophyta. The yeast plant, which is always produced during the fermentation of fluids containing organic matter, as also the Uredo, which constitutes the rust in wheat, and the Palmella nivalis, which produces the phenomenon of red snow, are all scarcely distinguishable under the microscope from certain pollen grains. These organisms might indeed be almost regarded as plants, which have been arrested at the pollen stage of their existence, and endowed with peculiar properties, among others with the power of reproduction.

The germ element, viewed in itself, is still more uniform and simple than the sperm, being merely a spherical or spheroidal corpuscle or cell. The receptacle in which it is contained, however, presents a greater variety in its aspect. In the vegetable kingdom, although it goes under diverse names in the different classes of plants, it is essentially a sac, consisting of one or more

envelopes, through which an opening penetrates down to the germ cell situated in the interior—this opening being provided for the admission of the sperm element. In some of the lower tribes of plants, however, as in the Algæ, there are several germ elements contained in one envelope, which is not furnished with an opening, but becomes ruptured to allow the germ cells to escape. Among plants, it is after the conjunction between the sperm and germ elements, that the spore or seed begins to be formed.

In the animal kingdom, the receptacle for the germ cell is the ovum or egg, which exists in all its essential parts, before union with the sperm element takes place. It presents a great uniformity of aspect—either a sphere or the well-known oval; nevertheless among insects, the eggs exhibit considerable departures from the usual shape. Eggs, though differing little in form, vary much in size—those of birds being in general the largest in proportion to the bulk of the parent. The eggs of some birds indeed are of enormous dimensions. An egg of the extinct bird, the Moa, which has been found in New Zealand, measures nine inches in its longer and seven in its shorter diameter. But even this is exceeded in size by the egg of an extinct bird, which has been found in Madagascar, and which measures no less than twelve and a half inches in its longer, and eight and a half in its shorter diameter.[1] The ova of animals which produce their young alive are generally very minute.

In the matter of eggs, the Rotatoria present a remarkable peculiarity—namely the production of more than one sort of egg by females of the same species. During the entire summer, they lay what are termed summer-eggs; but these are of two sorts—the one much smaller

[1] This egg is in the collection of George Dawson Rowley, Esq., that of the Moa is in the British Museum.

than the other, both, however, being of the usual oval shape. These two sorts are not laid by the same female; but one female will produce only the small eggs, and another only the large. The smaller sort give birth only to males, the larger to females—these last being of greater size and more highly developed than the males, which are very imperfect, having neither mouth nor stomach, nor any means of self-nutrition. They are consequently very short-lived, not surviving the lapse of twenty-four hours; whereas the females live eighteen days. Both the male and female summer eggs are so transparent that their internal changes can be observed, and they are hatched very soon after being laid. In autumn, the females begin to lay what are termed winter-eggs, because of their remaining torpid during winter, and not being hatched till the ensuing spring. They are larger than the summer-eggs, more irregular in form, and opaque, owing to the darkness of their granular contents and their being protected by a double shell—some being also covered with hairs or spines. The females, hatched from these winter eggs, are stated by some naturalists to have the power of multiplication by internal gemmation. Certain genera of the Entomostroca, for instance, the Daphniæ, or water-fleas, also produce two diverse sorts of eggs.

Some of the Annelida, as, for example, the Lumbricus, or earth-worm, and the Nais, especially the latter, produce what may be termed compound eggs, there being several eggs enclosed in a common calcareous envelope. Hence out of what appears to be a single egg, several young are hatched. An abnormal approach to something similar occurs among birds, which have been known to produce double eggs, one within another; but these are monstrosities.

The small tendency to variation of form, exhibited by the sperm and germ elements among plants and animals,

presents a striking contrast to the very great variety of forms assumed by perfect organisms in both kingdoms—especially among the lower members of the scale. This difference will become manifest on comparing the plates representing Foraminifera, Polycystina, and Diatomaceæ with that devoted to Pollen. The sameness of character in the last is strongly contrasted with the profuse variety exhibited by the others; while the Pollens are more diversified in form than are any other sperm or germ elements.

The circumstances attending the conjunction of the sperm with the germ element present three varieties. First. They may unite while both elements remain with the parent. This occurs in monœcious plants, and some hermaphrodite animals. Second. The sperm element leaves the parent before conjunction, while the germ element remains in the parental organism. This happens with diœcious plants, with all the higher animals and a large proportion of the lower. Third. Both the sperm and germ element leave their respective parents before conjunction. This occurs in the vegetable kingdom among the Algæ, whose spermatozoids and germ corpuscles are both discharged separately into the water. The spermatozoids, by means of their cilia, swarm around the germ elements and fertilize them; whereupon the latter, which at first consist merely of a primordial utricle enclosing a fluid, clothe themselves with a cellulose membrane or cell wall, and become cells capable of multiplication by cell division. The sperm and germ elements are also separately discharged into the water, in the case of most fishes and some other aquatic animals.[1] It is remarkable that, although in several of these cases both elements are cast into the water, and their subsequent

[1] One of the few exceptions among fishes is the Blenny, which being ovoviviparous must have concourse of the sexes.

conjunction appears left as it were to chance, the instances in which it fails to occur form a very small per centage of the whole.

There is a transitional case intermediate between the second and third—namely that exemplified by the frog, whose eggs are fertilized at the very moment of their quitting the female parent. The Argonaut presents another modification, which may also be regarded as transitional. In this case, the spermatozoa enter a long worm-like tube, which, separating itself entirely from the male, with an apparently spontaneous motion, attaches itself to the female, and by penetration impregnates her ova. This curious organ replaces one of the arms of the male.

Hermaphrodite animals present two principal varieties. In the one, the sperm and germ elements effect a conjunction, while both remain within the parent in which they were produced. In the other, an interchange of the sperm element between two individuals precedes its conjunction with the germ. The former mode presents three modifications. In the first, the conjunction is effected by access being obtained by the spermatozoa to the germ cells wholly within the parent, without any external aid or manifestation. This modification prevails among the Bryozoa, the Tardigrada, the Ascidians and the Bivalve Molluska. It is also found in the *Cerianthus membranaceus*, a hermaphrodite species of sea-anemone; although in that tribe generally the sexes are separate—the sperm elements being discharged into the water, and imbibed by the females, which are ovoviviparous. In the second modification of the first sort of hermaphrodite fecundation, the spermatozoa are brought into contact with the germ cells by means of an intromittent implement, with which the hermaphrodite is furnished, for the purpose of self-impregnation. Of this mode the tape-worms present an

example; and there is here another peculiarity—namely that the yolk of the egg is formed in a separate organ from that in which the germ cell has its origin. The third modification in the act of self-impregnation consists in there being required the concurrence of two individuals who, by mutual external pressure on the region of the generative organs, induce self-impregnation in each. Of this mode the earth-worm is an example. It forms a connecting link between the self-impregnating hermaphrodites and those in which mutual impregnation takes place. In this latter sort, while the sperm and germ elements are both produced in one parent, they do not unite there; but two such hermaphrodites come into close contact, and an interchange of their spermatozoa ensues—the one impregnating the ova of the other. This fashion prevails among the leeches, slugs, and snails. In the case of these last, the act is preceded by a curious dalliance, in which the enamoured pair pierce each other not metaphorically, but physically, with darts of love. The interchange of spermatozoa also occurs among some of the hermaphrodite Infusoria, in which it is effected through the mouth—the individuals adhering for this purpose by their anterior parts for several days.

There is a remarkable transitional case, forming an intermediate link between the hermaphrodite animal and that in which the sexes are quite separate. It is that of the male existing as an internal parasite within the female. This occurs in the genus Ibla, belonging to the Cirrhopoda, which are in general self-impregnating hermaphrodites. What is still more curious, these parasitic males occur in some species of Ibla, in which the principal organism is itself hermaphrodite; so that, in these cases, they are supernumeraries. A yet more gradual transition towards perfect separation of the sexes is presented by the Lernœa, in which the male subsists as an adherent exter-

nal parasite upon the female, herself a parasite on certain species of fish. Such parasitical husbands, it is to be feared, are not confined to the Lernœa.

From the facts before detailed—more especially from that of their uniting, in some cases, after both have left their respective parents, it appears impossible to deny that the sperm and germ elements are truly living organisms. They differ from generated and perfect organisms in these two particulars. 1st. They have no power of independent growth; but they grow as parasites on the parental organism, from which they draw nourishment. In this particular, however, they agree with perfect parasitical organisms. 2nd. They have, except in special cases to be afterwards noticed, no power of further development until after conjunction the one with the other—sperm with germ. By forming this conjunction, they appear either to originate a new being, capable of development into a perfect organism, whose nature depends on that of the uniting elements; or else the one element develops itself as a parasite at the expense of the other, which becomes absorbed and loses its independent individual existence. The sperm and germ elements may accordingly be termed elementary organisms. They are perfect in their kind, and are therefore to be distinguished from rudimentary organisms—those which are in progress of development; for of such development each is, for the most part, incapable of itself. They must unite, and on their union, either the one develops itself at the expense of the other, or both combine to form a new being which develops itself at the expense of both the uniting elements. The latter alternative will be afterwards shown to be the more probable of the two.

This faculty involves the retention of life and formative power by one or both elements, in certain cases after both have left their parental organisms, and in some instances

for long periods of time. It is this independent vitality that distinguishes the sperm and germ elements from all other products of the parental organism. No other cells, fibres, granules or corpuscles, save these alone, have this faculty of eventual ulterior development. They ought for this reason to be placed in a separate category, and regarded, not as mere products of organic growth, but as being truly organisms that have begun an individual existence.

This view is confirmed by the peculiar case of the Terebellæ, the marine worms which enclose themselves in tubes. Both the sperm and germ elements of these animals, while yet in a rudimental stage, escape from the organs in which they respectively have their origin into the abdominal cavity, where they float about freely in the fluid contents of that region, without having any further connection with the parent. In this situation they undergo development and attain perfection. The spermatozoa in particular pass through a series of changes somewhat analogous to those, through which certain perfect organisms attain full development. When first discharged into the abdominal cavity, the sperm element appears under the form of ovoidal masses—transparent, smooth, and seemingly homogeneous. In these masses there soon appear two grooves, at right angles to each other. These grooves increase in number and depth, till the whole mass becomes like a mulberry. This segmentation, which closely resembles that of the yolk of an egg, to be afterwards described, is attended by an increase in the bulk of the mass, to the extent of about one-half, both in length and breadth. The masses then break up and display the tails of the spermatozoa, which however continue to adhere together by their grosser parts, but ultimately separate one from another, and swim about freely in the liquid in which they are immersed. Here they

remain for some time longer, increasing both in length and breadth, until they are nearly doubled in both of those dimensions. When fully matured, they are ejected into the water in the neighbourhood of the female. She has meanwhile ejected in a similar manner the whole of her eggs, which continue adhering together, and to the mouth of the maternal tube, by means of a jelly. In this state they are surrounded and impregnated by the spermatozoa. Here these elements obviously possess a vitality distinct from that of the parent—a vitality in virtue of which they are capable, not only of a first development, but of a subsequent growth by self-nutrition—by absorbing the digested food supplied by the parent.

After conjunction between the germ and sperm elements, the spore, seed, ovum or egg, in which the united elements are thenceforward contained, may follow one of three courses. In the case of all spores, of nearly all seeds, and of a large proportion of eggs, they are discharged from the parent, and further development ensues at the expense of the contents of the spore, seed, or egg alone, until the offspring become capable of self-nutrition. The animals which thus extrude their eggs are termed oviparous. Other animals retain the impregnated egg in their interior till it be hatched. The embryo, however, is still developed at the expense of the contents of the egg alone, and is not indebted for any portion of its nourishment to the mother, from which the offspring issues alive, and capable of providing for itself. Such animals are termed ovoviviparous. In the higher animals, the impregnated egg remains in the mother; but the new being is not dependent on its contents alone for further development. The embryo becomes attached to the parent, from which it draws nourishment—growing and developing itself as a parasite on the maternal organism, whence, on attaining a certain stage of maturity, it comes forth alive. Such

animals are termed viviparous, and their habit is shared by a few plants.

It frequently happens that sexual generation by sperm and germ elements is concurrent, in the same organism, with one or more modes of individual multiplication, or with unsexual reproduction. In the vegetable kingdom such concurrence is very common, a large proportion of plants being capable of individual multiplication by buds or bulbs, while at the same time the species is propagated sexually by the conjunction of sperm with germ elements. The algæ present a more curious concurrence—namely, that of sexual reproduction, in the mode already described, with the conjugation of adjacent cells, after the manner prevalent among the desmids and diatoms. The result of this conjugation among the algæ is the production of sporangia full of spores, each capable of independent growth.

In the animal kingdom, the concurrence of sexual generation, with various modes of individual multiplication, is confined to the lower organisms. In the sponges, for example, it is concurrent with multiplication by irregular fission of the sarcode, and by gemmation both external and internal. In the coral polyps, while the individual is multiplied by buds, the species is propagated by sperm and germ elements. The situation in which these elements occur, and the mode of their conjunction, are somewhat peculiar in this tribe. The spermatozoa are developed in cysts in the folds of the stomach of the male, and when perfect are discharged into the stomach, whence they are straightway ejected by the mouth into the water. In like manner, the ova are first observed in the folds of the stomach of the female, and when ripe they are discharged into that cavity, which also receives the spermatozoa imbibed with the food. This is another proof that these elements possess independent life, which

enables them to resist the digestive action of the stomach. The ovum, having become impregnated, remains in the stomach till it is hatched; and the progeny—a pear-shaped ciliated embryon—is discharged into the water by the mouth.[1]

In the Hydræ or fresh-water polyps, sexual generation is concurrent with multiplication by irregular fission and gemmation. In this tribe, towards the end of summer, there appear, immediately under the tentacles, small conical protuberances which are filled with spermatozoa, and nigher the base there is, about the same time, formed a nearly spherical protuberance which contains the ovum. This ovum and the spermatozoa escape simultaneously into the water, and impregnation ensues. In some instances, these two sorts of protuberances occur on the same individual polyp, and in other instances, they are found on separate individuals. This peculiar mode forms a sort of connecting link between gemmation and ordinary sexual generation.

In Coryne and Tubularia, besides the two modes of gemmation already mentioned, there appear, at certain seasons, vesicles which contain what have been regarded as true ova. From each of these there is developed a new individual, which draws all its nourishment from the contents of the ovum alone, without obtaining any portion of it from the parent, with which all organic connexion ceases on the completion of the ovum; although the latter remains mechanically attached to the former by a small foot-stalk, till the embryo disengages itself. This case is remarkable from the circumstance, that no observer has yet been able to trace any spermatozoa, by which these ova become impregnated. Analogy maintains the expectation that they will yet be found, but in the

[1] *Quarterly Journal of Science*, October 1864.

meantime there here appears the anomaly of a germ element, seemingly capable of self-development, without the aid of the sperm, so constituting an intermediate link between gemmation proper and true sexual generation.

In certain of the Annelida, as for example the Cirrhatula, sexual generation is concurrent with a curious sort of gemmation, which seems intermediate between the ordinary formation of buds and multiplication by fission. These animals, which consist of numerous rings, each furnished with a pair of feet, grow by multiplication of those rings, consequent on gemmation from the penultimate ring. But at certain seasons, the gemmiferous power of this ring becomes more intense, and there bud forth from it not only new rings, but a new head, so forming an entire new animal, which eventually separates from the parent. This separation however is sometimes delayed, until several such new individuals are formed in a chain, all appended to the parent, whose tail is appropriated by the first formed offshoot, and constitutes the extremity of the chain. In some genera, *e.g.* in Syllis, at certain periods, there is produced by this sort of gemmation a new individual, which is entirely set apart for sexual reproduction, and does not multiply itself by segmentation.

In the compound forms of the Ascidian Mollusks, there is a concurrence of multiplication by gemmation with hermaphrodite generation. The individual produced from the fertilized egg is at first free-swimming; but it ere long becomes fixed, and undergoes a change of form. It then produces by gemmation numerous other individuals like itself, which all adhere closely together, forming a colony. Each of these individuals is a self-impregnating hermaphrodite, producing both spermatozoa and ova, whence springs a new generation of free-swimming indi-

viduals, each of which becomes the founder of a new colony.

Other instances of the concurrence of sexual generation with unsexual reproduction occur in connection with the phenomena of fertile nurse-forms, and will be noticed hereafter.

Such, and so various, are the means to which the Creator has had recourse for securing the multiplication of individuals, and the propagation of species in the organic world.

CHAPTER XVIII.

PRIMARY DEVELOPMENT.

Primary development, both in the animal and vegetable kingdoms, has its origin in an embryo.

Among plants, the embryo is either naked, when it is called a spore, or it is enclosed in a receptacle which, together with the embryo, constitutes a seed. Spores receive diverse designations, according to the manner and situation in which they are produced, and their behaviour after production. They may be produced—1st, by the sexual conjunction of a sperm with a germ element; 2nd, by the conjugation of two cells undistinguishable the one from the other; or, 3rd, by simple cell-multiplication. In this last case, the spores are more of the nature of bulbs, being the result of mere vegetative growth, not of any procreative act. In some of the simpler fungi, the spores are borne at the end of filaments, either free, or in a little sac or pod called a *theca*, when the spores contained in it are called *theca-spores*. Sometimes the spores are piled one upon another in columns, and they are then called *stylo-spores*. In others of the fungi the spores, generally in groups of four, grow at the end of a minute foot-stalk called a *basidium*, whence they are termed *basidio-spores*. Those of the edible mushroom are of this sort, growing on the so-called gills. The spores of the lichens are all theca-spores. They differ only as regards the manner in which the *thecæ* or pods are disposed, some being contained in chambers formed either in thickened parts of

the thallus, or in special branchlike lobes—these chambers opening externally by a minute pore; while in other genera the pods are borne upon an open cup, or shield-shaped or linear body, which is either sessile or stalked on the thallus. The *tetraspores* and *zoospores* of the algæ have been already noticed. They are of the nature of bulbs, being produced by mere vegetative growth. But besides these, the algæ—at least the higher orders among them—have true spores, the result of a generative act, in some cases of conjugation, and in others of sexual conjunction, in the manner already described. The spores resulting from conjugation may be regarded as a connecting link between those produced by sexual conjunction and those arising from gemmation.

In the ferns and horsetails, the spores produced by the perfect plant result from gemmation, and are of the nature of bulbs. These embryos become developed, not into the perfect plant, but into an intermediate form, called the prothallium, on which are produced the ciliated spermatozoids and germ-cells. These again by their union produce true spores, which by their germination are developed into the perfect plant.

Some ferns, especially those belonging to the genus Asplinium, present a double gemmation in the perfect plant: for, besides the spores on the back of the frond, they occasionally produce on the upper side a bud which becomes developed into a fresh frond; so that we have one frond growing from the upper surface of another.

Spores are embryos consisting either of a single cell, or of an aggregation of such. They are developed into plants by cell-growth and multiplication. In the lower orders, the whole plant consists of mere cells or cellular tissue; but in the higher orders of flowerless plants, the cells become modified into membranes, tubes and fibres; while out of these or their combinations various tissues

are elaborated. It is easy to see how one or more layers of cells, by being compressed in one direction, should become modified into a membrane, how a row of cells opening one into another should become a tube, and how such a tube, by shrinking or compression in every direction save that of its length, should become a fibre. Nor is it difficult to perceive how, in this last case, if the shrinking be greater or more rapid on one side of the tube, the resulting fibre should tend to wind itself into a spiral.

In its development, the spore of each species is governed by special laws of its own; so that, however great the resemblance which one spore may bear to another, when examined under the microscope, still, in its development, each follows its own course, and ultimately gives rise to a plant similar to that from which it sprung.

From their great simplicity, spores resemble pollen more than seed. They correspond, however, not to the pollen, but to the embryo contained in the seed of flowering plants. The true representatives of the pollen are the spermatia and spermatozoids of the flowerless plants.

The embryo in seed-bearing plants is the result of the conjunction of the pollen with the germ-cell contained in the ovule. During the earlier stages of its existence, it becomes enveloped in one or more integuments, and in many plants it becomes also embedded in a mass of tissue called the *endosperm*, which in some cases affords nourishment to the embryo during its germination. In the seeds of the higher orders of flowering plants, the embryo consists of a radicle or rudimentary root, a plumule or rudimentary terminal bud, and one or more cotyledons or rudimentary leaves—thus possessing, even before germination, all the essential kinds of organs requisite for vegetative growth. In other orders of flowering plants again, as in the Orchids and Orobanchaceæ or broom-rapes, the embryo contained in the ripe seed is a mere

cellular nodule. This constitutes a sort of transitional link between the spore and the more perfect sort of embryo.

For the germination of seeds, there is required a supply of moisture and oxygen, and a certain degree of warmth. But light, so favourable to the health of plants after they spring from the seed, is prejudicial to germination. The water and oxygen, penetrating the integuments of the seed, are imbibed by the embryo, whose growth is thus stimulated. It increases by the enlargement and multiplication of its component cells, until it burst the integuments of the seed, and emerge as a young plant, resembling that by which it was produced.

While the vegetable cells grow and multiply, and become transformed into membranes, tubes, fibres and other tissues, certain chemical changes also accompany the development of the embryo. The contents of the cells are generally water holding in solution sugar and gum, oil globules, and either starch or inulin; while the cell-wall and primordial utricle are composed of the substance called cellulose. All these materials, except the oils, differ little one from one another in constitution, being composed of a definite quantity of carbon, with a varying quantity of oxygen and hydrogen, in the proportion which constitutes water. Thus, regarding each as composed of twenty-four equivalents of carbon, the equivalents of water combined with these are in cane-sugar eighteen, in grape-sugar twenty-one, in gum-arabic twenty-two, in starch twenty, in inulin twenty-one, and in cellulose twenty. Hence, by a change in the proportion of water, or by an alteration of the manner in which the elements are arranged in the combination, these substances may be mutually converted one into the other. The germination of seeds is generally accompanied by a conversion of starch into grape-sugar,

through its acquiring an additional equivalent of water; while by a loss of that equivalent, probably attended with a new arrangement of the elements, sugar is converted into cellulose, to form the primordial utricles and cell-walls of the new cells. The cells of some spores and seeds contain, besides oil globules, vegetable albumen; and these two become resolved into chlorophyll, dextrine, and other combinations.

But the power chiefly characteristic of vegetable growth, is that of converting inorganic materials into organic substances. Of this power, the fungi and the colourless parasitic plants are nearly, if not altogether, destitute — these plants assimilating only already organised materials. But all other plants, while they do not refuse materials already organised, and have their growth stimulated by such, are nevertheless adding continually to the store of organised material in the world, by virtue of their powers of assimilating inorganic matter. Sometimes, indeed, such inorganic substances, while taken into the system of the plant, and acted upon by the formative faculty of its organizer, remain inorganic still. Of this we have examples in the siliceous valves of the diatoms, in the calcareous incrustations of the corallines, in the crystals called raphides found in the cells of some of the higher plants, in the other crystals named crystolithes, which accumulate in processes formed on the cell-walls of other plants, and in the tabasheer, so remarkable for its low refractive power, found in the hollow joints above the nodes in the bamboo.

The inorganic elements which plants are capable of actually assimilating, are oxygen, hydrogen (or their combination water), carbon, nitrogen, chlorine, iodine, bromine, fluorine, sulphur, phosphorus, silicon, potassium, sodium, calcium, magnesium, aluminium, manganese,

iron, zinc and copper. The first four occur universally in plants, while the last four are found but rarely. Some physiologists add arsenic to the list, but deny the presence of aluminium, notwithstanding its abundance in soil. None of those materials enter the plant in a free state except oxygen. The most abundant is water, which forms from ninety to ninety-five per cent. of the whole. Of the remainder, two-thirds generally consist of compounds of carbon, hydrogen, and oxygen; while the alkalies, earths, and metallic oxides constitute from one to four per cent., and in rare instances twenty per cent., of the solid materials of the plants. Chlorine, iodine, and bromine occur chiefly in marine plants, being absorbed from the sea-water. Silicon abounds in the grasses and horse-tails.

The materials must be reduced to the gaseous or liquid condition, in order to their being assimilated by a plant. The oxygen, hydrogen, nitrogen, and carbon are derived chiefly from the atmosphere; but a large proportion of the water contained in plants, and the other materials generally, are derived from the soil in which they grow. Plants which live wholly immersed in water obtain all their sustenance from that liquid and the materials which it holds in solution.

The living organizer of each plant—the being endowed with that formative faculty by which its tissues are elaborated, is also a very subtle chemist, capable of forming combinations that baffle the skill of the most astute chemist of the human race. Although the latter can by analysis determine the exact composition of most of the products of the former's art, he is nevertheless unable to effect these combinations by synthetic skill, if he be supplied only with the inorganic materials, whence they are elaborated by the organizer of the plant. Man, indeed, when furnished with organic compounds ready to

his hand, can convert one of these into another, or even wholly alter their constitution, by introducing into them one or more extraneous elements, or by substituting one element for another; and he may thus produce substances not found at all in the laboratory of nature, and which may therefore be regarded as in some measure the exclusive products of his skill. But supply a chemist with any quantity of oxygen, hydrogen, and pure carbon, and he is unable so to combine these as to form sugar, gum, oil, wax, starch, inulin, cellulose, or any of the vegetable acids, nor can he discover the nature of that diversity of arrangement which makes inulin differ from grape-sugar, or starch from cellulose. Far less is he able, when supplied with nitrogen, in addition to the other above-named materials, to form any of the complex combinations into which this element enters—such as morphia, quinine, strychnine, theine, and other vegetable alkalies. Still more complex and beyond the power of human manufacture are vegetable casein, into which, along with the four ingredients above enumerated, sulphur enters as an element, and vegetable albumen and fibrin, of which phosphorus as well as sulphur forms a component part.

Primary development is more variable in the animal than in the vegetable kingdom. Some animals, indeed, are so simple, that development cannot be said to occur in them at all. In the Amæba, for example, which consists of nothing but sarcode, there is growth, and increase in the mass of sarcode, but there is no other substance elaborated out of it, and not even any definite form ever assumed. There is here, therefore, nothing that can be called development. Even in the case of the Foraminifera and the Polycystina, which likewise consist only of sarcode, although the organizer is in them endowed with wonderful formative powers, in virtue of which it moulds either lime or silica into shapes of

marvellous beauty, there is no development of the animal itself—nothing but growth of sarcode. The gradual formation of the shell is simply the consequence of that growth, combined with the action of the formative power of the living organizer. But this is quite a different thing from that development of various tissues and organs which occurs in the generality of animal organisms.

Some of the infusoria which, in the course of their development, undergo metamorphosis, pass through an amæba-stage in their existence, and such amæba-forms become further developed; but these are not to be confounded with the true amæbæ, which undergo no development. All sarcode, however, exhibits a tendency to form within itself void spaces termed vacuoles, and these perform an important part in further development where such eventually ensues. The existence of vacuoles in the true amæba may accordingly be regarded as an evidence of a predisposition towards development, although none actually occurs. The next progressive step is the acquisition by these vacuoles of a lining membrane, when they become contractile. They then put forth into the surrounding sarcode rays, which are likewise endowed with contractility, and there are thus formed the rudiments of a vascular system.

In many of the infusoria, development takes place simply by cell-growth and multiplication, as among plants; but in others—chiefly those which pass through subsequent metamorphosis—there is a departure from this mode, and new tissues and organs are fabricated, after the embryo becomes capable of self-support. The embryo, in most of such cases, is a mere ciliated corpuscle, resembling the zoospores or spermatozoids of some of the flowerless plants. In certain genera, these ciliated corpuscles force a passage for themselves through the parental sarcode,

which immediately closes up after their escape, and they become thereafter developed into the perfect animal, by a series of metamorphic changes.

In the case of the Spongiadæ, it would almost appear as if the animal suffered degradation in the course of its ulterior development; for, on its escape from the parent, the embryo is an ovoidal ciliated animalcule, which swims about by means of its cilia, with great activity, until it find a fitting place on which to fix itself. It then loses all its locomotive power, and becomes developed into a mere layer of sarcode, apparently endowed with powers of growth and a wonderful plastic faculty, in virtue of which it forms its horny or siliceous frame, and its beautiful spicules. But as regards its mere animal constitution, apart from its frame and its spicules, it remains mere sarcode; it undergoes no further development, but only grows to a greater size; unless indeed the formation of spermatozoa and ova can be regarded as development.

In the case of those Infusoria which multiply themselves by regular fission, there is, in each instance of self-division, a development of certain new parts by each half of the organism, in order to render it a complete whole; but there is one particular internal part called the nucleus, which always becomes divided between the two halves. This nucleus is denser than the general mass of the animalcule, and it is uniformly accompanied by a smaller body, called the nucleolus—these names being given from a supposed analogy to similar bodies found in vegetable cells. But the nucleus and nucleolus of an animalcule are now, with great probability, regarded as the first rudiments of generative organs—the former appropriated to the germ, the latter to the sperm element. In some of the higher forms of the ciliated protozoa, according to some observers, these two bodies

actually do perform generative functions—ova being produced in the nucleus and spermatozoa in the nucleolus; while these two by their union originate the embryo, which ultimately becomes developed into the perfect animal.

It is this development of the embryo from the ovum or egg that, in a more special manner, illustrates the process of primary development in the animal kingdom.

The egg consists of two parts, which are primarily distinct, sometimes in origin, always in function. These are the germ and the yolk. They are sometimes distinct in origin; for in the case of the tape-worm, the germ and the yolk are formed in separate organs, situated in different parts of the body. The germ descends through one channel and the yolk through another, and on their meeting they unite. They are always distinct in function—the germ being that which, on combining with the sperm element, becomes transformed into the embryo—the yolk being a supply of organised material, at the expense of which, in part at least, the development of the embryo is accomplished. The germ itself consists of two parts—the germinal vesicle and the germinal spot—both being spheres, and the latter within the former. The yolk also consists of two parts—a spherical granular mass which constitutes the yolk proper, and a membrane which envelopes both the granular mass and the germ. Besides these the essential parts, some eggs are furnished with one or more integuments, and in oviparous animals the outermost covering is either a hard shell, or a horny or leathery case, designed for protecting the contents from injury.

In all cases the germ of the egg is very minute, but the yolk varies much in magnitude, and in the proportion which it bears to the germ. This proportion is greatest in birds; while in viviparous animals the yolk is

extremely small. In most cases, the whole of the granular matter is absorbed, and appropriated by the embryo in the course of its development; but in some instances, as in fishes, only a portion of the yolk is thus appropriated, and the remainder, enclosed in a bag, continues attached to the belly of the young creature, and affords it a supply of nourishment, for a considerable time after its escape from the egg.

In viviparous and ovoviviparous animals, observation of the process of development is difficult, as it is also in the case of those oviparous animals whose eggs are opaque. It is only in those few which have transparent eggs, that the development of the embryo can be watched continuously. In all the others, the successive stages can be observed only at intervals, and the observation destroys the embryo. Among the eggs having the requisite transparency for continuous observation, are those of the Hermella, an annelid, and of the Teredo or ship-worm, a mollusk, as also the summer-eggs of the Rotatoria. A comparison of the phenomena exhibited by these eggs during their earliest stages, with those presented by the eggs of other animals belonging to the various orders from the lowest to the highest, made as opportunity has allowed, shows that the earliest changes which occur in the egg are common to all alike, from the human ovum down to that of the lowest organism in which an egg has been traced.

The first phenomena observable in the egg are exhibited independently of impregnation. They consist in the yolk's becoming agitated and the germ invisible. An almost universal sequence to these changes is the escape from the yolk of one or two transparent globules—the eggs of certain two-winged insects presenting an exception. If the egg has not been impregnated, the agitation of the yolk increases and ends in decomposition. But in the

fecundated egg, the phenomena above described are followed by a brief repose, preparatory to the next step, which is the segmentation of the yolk. This process begins by the appearance of a circular groove about the middle of the sphere. Deepening rapidly, this groove is soon crossed at a right angle by another. In quick succession other grooves appear, crossing one another until the sphere assumes the aspect of a mulberry. But the grooves and the vesicles, into which the yolk seems to be divided by them, go on increasing in number, until eventually the sphere almost regains its former smoothness of surface. In some eggs having a proportionately large yolk, a portion of it escapes this process of segmentation, which is somewhat similar to that of cell-division in the lower organisms. In all cases it results in the formation of the germinal membrane—an organised layer embracing the yolk. At this point, the resemblance between the eggs of the Vertebrata and those of the Invertebrata ceases, and the phenomena they exhibit rapidly diverge.

In the Vertebrata, the next succeeding stage is an accumulation of cells and granules at a particular point in the germinal membrane, where they form a small spot named the germinal area, which becomes the centre of future action. Rapidly extending, this area assumes an oval form, whose greater axis becomes marked by a transparent line called the primitive streak. This is the first indication of the spinal cord, and ere long it exhibits a series of obscure points, the earliest rudiments of the vertebral column. From this stage divergence again begins, and the different classes and orders of the Vertebrata follow diverse courses of development. In those which are oviparous, the yolk is already enveloped in albumen, which performs an important part in the further development of the embryo. But in the mammal, it is not till after the formation of the germinal membrane

and area, that the egg acquires an albuminous layer, probably secreted by the primary membrane of the yolk. In all the mammals, the egg is, up to this stage, free and unattached; but in the placental orders, it soon begins to extend delicate folds, which eventually become rootlets, dipping into the substance of the maternal womb, for the purpose of thence absorbing nourishment.

In the Invertebrata, the phenomena which follow the formation of the germinal membrane are diverse, and more or less complex, according as the animal is perfected in the egg, or subsequently undergoes metamorphosis, which is simply a continuation of development. In this last case the animal, on leaving the egg, is still an embryo; but it is capable of self-nutrition. From the incompleteness of its development on its leaving the egg, it is often a very rudimentary organism at that stage of its existence; so that the further processes, which take place within the egg, are few and simple. In the Hermella and Teredo, for example, the membrane of the yolk increases in thickness, and adapts itself to the enclosed embryo. There then appear on its surface a few cilia, which, after remaining still for a while, begin to vibrate. These soon increase in number, and in the rapidity and constancy of their vibrations. The egg has thus become transformed into a larva, which, after lifting itself from the surface on which the egg had rested, and poising itself for a while, darts off and swims about rapidly under the guidance of the creature's will. In the case of both of those animals, the yolk-membrane becomes the skin of the ciliated larva. In the rotifers also, the first step, after the formation of the germinal membrane, is the appearance of vibratile cilia in two places—one set where the head, and the other where the stomach is to be. The vesicles into which the yolk has become divided by segmentation then seem to coalesce, and out of its substance the various organs of

the animal are elaborated by slow degrees—the cilia being all the while in constant action. In this case, the animal attains much greater perfection within the egg than does either the Hermella or the Teredo.

Primary development in the case of the sea anemones is also very simple. These animals are ovoviviparous. The embryo is at first of an egg-shape; then a depression appears at one end. At the bottom of the little cup thus produced, there is formed another opening, which extending downwards expands into a chamber. This becomes the stomach, while the opening above constitutes the mouth. The upper margin of the latter enlarges, and there soon appear on it small prominences, which eventually lengthen into the tentacles. Beneath the stomach, again, there is formed a lower chamber, which becomes the site of the reproductive organs. The substance of the embryo at the same time undergoes a great change, and from a simple jelly it passes into a complex and highly elaborate tissue—embracing the curious filiferous capsules, as they are termed, which are characteristic of the order.

In the most perfect animals there may be distinguished four groups of organs: first, those which subserve the purposes of volition; second, those appropriated to the reception and digestion of food; third, those which serve to distribute the products of digestion to every part of the organism; fourth, those set apart for reproduction.

In the simplest animals—those composed entirely of sarcode—all these functions are performed by the sarcode itself, without any variation in its structure. The entire mass seems to be obedient to the will of the animal, which can outstretch, or retract, or infold, or disintegrate any portion of it at pleasure. When an organised substance, fitted for its food, touches its external surface, it becomes by the will of the animal quickly drawn into the mass of the sarcode, which soon envelopes it on all sides. There

is thus formed an extempore stomach, which speedily digests and assimilates all that is digestible of the enclosed substance. In like manner, the animal seems to have the power of drawing into the sarcode bubbles of air —forming vacuoles, which may be regarded as the first indications of a respiratory and circulatory system. Finally, the sarcode divides itself into numerous small portions, which become the germs of new beings—a very rudimentary mode of performing the function of reproduction.

But as organic development proceeds to higher and higher stages, diverse tissues and organs become successively appropriated to the performance of those different functions. The tissues and organs subject to the will increase in number and complexity. Then some are withdrawn from that control, and set apart for the purpose of nutrition. A cavity is formed with a lining membrane, which secretes a solvent juice. Into this cavity the food is received and there digested into a nutrient fluid, which is at first merely absorbed. By degrees this simple apparatus becomes more and more complex—acquiring increased power to digest and assimilate a greater variety of substances. It is furnished with means for throwing off the undigested refuse both solid and liquid—together in the lower, separately in the higher organisms. It is aided by a supplementary organ, the liver, which secretes a special fluid—the bile, an important agent in digestion. There is added in the higher orders another supplementary organ, the pancreas, which also secretes a special juice to promote the process of assimilation. Then follow appropriate instruments for preparing the food, before its reception into the stomach, as the gizzard, the mandibles, the jaws armed with teeth, the mouth furnished with salivary glands, &c. For the assimilation of certain kinds of food, the stomachs are multiplied, as in the ruminants. For the better distribution of the nutrient matter derived

from the food, the stomach is prolonged into the intestinal canal, which in many animals acquires an extraordinary development. Indeed, in some of the naked mollusks and a few other animals, thence termed *plebenterate*, the intestines become so ramified through all parts of the body and limbs, as to supersede the necessity of any separate apparatus for circulating the nutrient fluids, such as exists in the vascular system of the higher animals.

This latter system of organs is also removed from under the control of the creature's will. Its first rudiments appear in the radiated contractile vacuoles, already mentioned as being found in some of the Infusoria—an advance upon the simpler vacuoles of the Amœba. The next stage of progress is the water circulation in certain of the Infusoria and the sponges. Then comes the vascular circulatory system, with the heart for its centre. This organ, at first a simple tube, ultimately becomes, in the highest mammals, a complex strong muscular mass, with four chambers. In connection with the veins and arteries, it serves, on the one hand, to distribute the nutrient fluids derived from the food to every part of the organism, and, on the other hand, to withdraw from the system the materials which have ceased to be useful. It is generally connected with another set of organs, designed for the exposure of the nutrient fluid to the action of air, either as it exists in the atmosphere or is found in union with water. This aëration is required to enable the nutrient fluid to absorb oxygen and give off carbon, these actions constituting respiration. The respiratory organs vary, both in their character and in their position in the organism. Where the respiration is conducted under water, the organs must be in immediate contact with that fluid, to enable them to absorb from it the oxygen which it holds in union. They are then termed branchiæ, or gills, and are situated sometimes near the head, sometimes

on the back, or on the breast, or on the sides, or appended to the feet, or near the hinder extremity of the body. But in some aquatic animals, respiration is performed through the skin, or certain portions of its surface.

Where the creature breathes the external air, there are two distinct modes of respiration. In the one, the nutrient fluid, the blood, is by means of the heart driven to a special set of organs, the lungs, where it is distributed over a large surface in minute capillary vessels. The lungs being seated in a cavity to which the air has free access, the blood thus becomes aërated by being brought into contact with its oxygen, which passes by dialysis through the walls of the capillary tubes. In the other mode of atmospherical respiration, the air is introduced through small holes in various parts of the body, and circulated in tubes through the entire organism. Hence the nutrient fluid becomes aërated through the whole system, and not in any special organ appropriated to the purpose. This is the mode followed in insects. There is in birds a sort of combination of both of these modes, for not only are they provided with lungs for the aëration of the blood, but the air is also, as in insects, admitted to circulate through their whole system, even through their bones. In some of the lower air-breathing organisms, as the worms, the aëration is effected through the skin, or through minute pores in that integument.

The voluntary system of the organism embraces all those tissues and organs, which are subject to the animal's will, being appropriated to the functions of voluntary motion, sensation, thought, instinct, reason. They comprehend the bones, sinews, muscles, and nerves, which subserve the purposes of motion, in obedience to the impulses of the will, together with the organs of sight, hearing, smell, taste, and touch, the nerves which give their sensitiveness to those organs, as also the nervous centres, the

ganglia and the brain, constituting the means by which the organizer exercises its powers of thought, instinct, and reason, probably also the ultimate centres of the perceptions of temperature and equilibrium.

In the Amœba, the voluntary system exists in the most extreme simplicity, its functions being reduced to two—voluntary motion and the sense of touch. These are both performed by the sarcode, of which alone the animal consists, and the whole of which the will of the organizer seems to pervade. The entire surface of the sarcode is the organ of touch, and for voluntary motion the means are provided as occasion may require, in the form of the processes which the animal puts forth and retracts from time to time. The first advance from this simplicity appears in the root-like feet of the rhizopods, these being merely a more persistent form of the temporary processes of the Amœba. Vibratile cilia may also be regarded as an advance, these being specially appropriated both to locomotion and the sense of touch; at least, that sense seems to be usually more delicate in the cilia than in the general surface of the body. These organs attain their highest perfection in the so-called wheels of the rotifers. The bristles and hooklets of some of the Infusoria are likewise an advance in development, these being appropriated to locomotion; while the retractile stems of the Vorticellæ combine a limited motive power with extreme tactile sensitiveness. Tentacles as organs of touch, and as instruments of locomotion or for the seizure of prey, are an improvement on cilia. Then succeed members appropriated to voluntary motion, as the propulsive and prehensile tail, rays, fins, legs, arms, wings, &c. Sometimes such appendages are discarded, and locomotion is obtained by contractile rings, or by a peculiar arrangement of ribs, or by a single muscular foot placed near the head or on the belly. Occasionally the branchiæ

or respiratory organs are employed for instruments of propulsion, as in the pretty little Eolis, whose iridescent branchiæ are convertible into a bank of oars, when the mollusk paddles, back downwards, through the water. In other cases progression is effected by the forcible expulsion of water from a reservoir, into which it is introduced by a highly absorbent skin. The sense of touch is sometimes separately provided for by distinct organs, called *palpi* or feelers, where the general surface of the body, as in insects, is ill adapted for the purpose. In fishes this sense resides chiefly in the lips and the pectoral and ventral fins; while in birds it is supposed to be concentrated in the bill and soles of the feet.

Of the other senses, that of sight is the earliest to be developed, the organ consisting at first only of a crystalline lens and the retina, and appearing merely as a red or black spot. Gradually it assumes greater perfection, until it culminates in the birds of prey, whose eyes are more perfect than those of the highest mammals, being furnished not only with an additional eyelid or nictitating membrane, but with a more perfect means of adjustment for far and near vision.[1] Eyes are of two kinds—the single and the compound, which latter are confined to the insect tribe and the crustaceans; some of these latter having also a sort of eye intermediate between the simple and the compound, termed the agglomerated, in which several simple eyes are placed behind one common cornea. Both the compound and the agglomerated eyes are designed to afford a large range of vision without motion of the head, But this end is also sometimes attained by placing simple eyes on a peduncle or footstalk, turning in every direction, as exemplified in some of the crustaceans. In other cases the capacity of seeing

[1] The nictitating membrane is found also in several reptiles and fishes.

in various directions is conferred by increasing the number of single eyes, and distributing them over various parts of the body—some annelids having eyes on the tail as well as on the head, while others have them arranged all along their sides. Several of the bivalve-mollusks also, as the Pecten and a few others, have eyes disposed all round the margin of their mantle. On the other hand, some animals, otherwise high in their organisation, are destitute of eyes, owing either to their inhabiting dark places, such as caverns or subterranean lakes, or to their peculiar mode of life's rendering sight unnecessary. In the latter case certain animals, which are thus blind in their mature condition, are in their more active larval state endowed with eyes, which in the course of their further development they lose, on their becoming no longer needful, owing to the animal's leading a stationary life, and obtaining all its food by means of tactile organs.

The organ of hearing begins to appear somewhat later than that of sight, although it is supposed to occur as early as in the Medusæ. At first a mere vesicle, it becomes by degrees elaborated into the complicated organ found in man, which is adapted to appreciate the most delicate gradations of sound. In the invertebrate animals, and the lower vertebrate, the organ seems designed to convey only an impression of noise. This conclusion is confirmed by the means adopted to heighten such an impression, namely, the introduction into the organ of small loose-vibrating bodies, termed *otolithes* or ear-stones. These, while tending to augment the vibratory action brought to bear upon the nerve, must be utterly destructive of anything like variation of tone. Such otolithes are found in the ears of fishes, and some of the cephalopods or cuttle-fish tribe. They are little hard masses of definite form, composed of carbonate of lime, and frequently occur in the fossil state. In the ear of the

lobster, there are substituted for these otolithes, which are of organic formation, minute grains of silica, which are purely mineral in their nature, but answer the same purpose of forming rattles in the ear.

Some of the more perfect fishes have a connection established between the air-bladder and the ear, in order to augment the resonance. In insects the antennæ are supposed to be the organs of hearing. If so, the impression conveyed must, in their case also, be that of mere noise, produced by the vibration of the antennæ, as of a spring, in sympathy with the tremors of the air. In the mammal, the organ of hearing is a highly elaborate instrument, beautifully adapted by its mechanism to subserve the purpose for which it is designed. This organ attains its greatest perfection in the human ear, with its tympanic membrane, closing the air-filled drum with its valve-guarded tube for regulating the pressure of the enclosed air, its hammer, anvil, and stirrup, as also its wondrous water-filled labyrinth, over whose lining membrane are distributed the terminal fibres of the nerve of hearing, intermingled with sharp-pointed elastic bristles, adapted to sympathise with the tremors of the water of the labyrinth,—in another part of which, embedded among the nervous filaments, are minute otolithes, serving to augment the intensity and prolong the continuance of the vibrations; and in which lastly is found, most marvellous of all, that harp of thrice a thousand strings, calculated to vibrate in unison or harmony with every variety of sound which may fall upon it from the outer world.

The sense of smell does not appear to exist in any tribe of animals lower than the insects, and it attains a higher perfection in some of the inferior animals than in man. The sense of taste, again, seems to be confined to the mammals, and to be most perfect in the human species, for which it is most needful. Man, living on a

far greater variety of food than any other animal, required an organ of taste sufficiently delicate to discriminate the vast variety of savours with which it is brought into contact. It is probably owing to the extreme nicety of the discerning power of this sense in man, that its name has been transferred to those refined discriminations, which are summed up in the word 'taste,' when applied to the mind.

These three organic systems, of which the foregoing is an imperfect sketch—namely, the alimentary, the circulatory, and the voluntary—are early differentiated in the embryo of the higher organisms. When the germinal membrane, formed after the segmentation of the yolk of the egg, is carefully examined, it is found to consist of three layers. From these all the envelopes, tissues, and organs of the embryo are developed. From the outermost layer are formed the amnion and the chorion—the former secreting an abundant fluid in which the embryo floats, the latter eventually constituting the medium of connection between the embryo and the maternal womb, becoming overspread with blood vessels, and transformed into the placenta. From the two other layers is formed the allantois, which is applied closely against the inner surface of the chorion. It is a membranous bag, full of veins and arteries communicating with those of the embryo. The connection of the embryo, first with the allantois, and subsequently with the placenta, becomes eventually limited to the umbilical cord. All these parts are mere accessories to the embryo itself, which is developed from the germinal area. This last, like the germinal membrane on which it is situated, consists of three layers, and it is from these that the three great organic systems take their origin. From the outermost layer is developed the voluntary system—the brain, spinal cord, nerves, bones, and voluntary muscles.

From the innermost layer arise the organs and tissues pertaining to the alimentary system, and from the intermediate layer is developed the circulatory system, comprehending the heart, veins, arteries, &c.

Development takes place chiefly by two processes—fabrication and growth. The tissues and organs, having been first as it were sketched, are next moulded into definite form, and then augmented by simple growth. When the embryo is nourished from the contents of the egg alone, the chief supply is furnished by the yolk; the nourishment being conveyed to the embryo through a tube, which usually enters at once into its belly, but in the exceptional case of the cuttle-fish tribe, into its mouth. The marsupial animals, such as the kangaroo and the opossum, form a connecting link between those whose embryos are nourished entirely from the egg and those whose embryos, after a certain period, draw all their nourishment from the maternal womb, by means of the placenta. The marsupial embryo never forms any vascular connection with the womb of its mother, which is accordingly ovoviviparous; but, after all the nourishment afforded by the egg has been exhausted, the embryo, still in a very immature state, is transferred from the womb into an external pouch attached to its mother's belly, and is there nourished throughout the further stages of its development by milk from the maternal nipples, to which it adheres by its mouth.[1] The embryo

[1] Pouches as organs accessory to generation are not confined to the Marsupialia. They are found also among reptiles and fishes. In *Nototrema* and *Opisthodelphys*, for example, belonging to the former class, the eggs are after impregnation transferred to a large pouch in the middle of the back of the female, where they are retained till they are hatched. In the *Pipa* or Surinam Toad, the pouches on the back of the female are numerous, there being one for each egg. In these cases the eggs are placed in the pouches by the male. Among certain fishes, such as the *Hippocampidæ* or Sea-horses, and the *Syngnathidæ* or Pipe-fishes, there is a similar provision for retaining the eggs till they are hatched; but in their case the pouch is situated

being too feeble to suck, a provision is made by which the milk is injected by the mother, and passes down the throat without interfering with the respiration, which is sustained through a separate air-passage, guarded by a partition, on either side of which the milk trickles down into the gullet.

In the egg-nourished embryo, the alimentary system is the earliest developed, because it is through it that nourishment is supplied; but in the womb-nourished embryo, the circulatory system is more rapidly perfected, because during the whole period of fœtal growth, it performs the alimentary function, which is carried on through the medium of the blood-vessels. The voluntary system, comprehending the limbs and organs of sense, is completed at a later period. In some cases, the organs of sight are not perfected till after birth. The limbs are always very rudimentary at first, and sometimes change their relative proportion to each other. Thus, in the human species, the fœtus at an early stage has a tail, as long in proportion to its other members, as that of most other animals. At that period, the legs and arms are mere rudiments of limbs, and the embryo, in the general outline of its form, somewhat resembles a species of seal. But an arrest is soon put on the tail, and the other members speedily outgrow it; so that, in the fully-developed child, the once prominent appendage can hardly be traced.

In the course of development it occasionally happens, that organs and tissues are formed to subserve only a temporary purpose, and that some organs perform, at one period, a different function from that for which they are ultimately destined. Hence, in addition to the processes

under the tail of the male fish. In the *Holconoti*, another tribe of fishes, the young are retained in a similar pouch until they acquire full development and about a third of the size of the parent.

of fabrication and growth, there must also be recognised those of obliteration and alteration. The most remarkable examples of temporary organs are those known as the Wolffian bodies, which appear at an early period, and stretch from one end of the body to the other, on either side of the alimentary canal. They seem to be a sort of temporary kidneys, and they become absorbed when the true kidneys are developed. As an example of alteration, may be cited that which takes place in the mammalian heart, in order to adapt it to the change in the circulatory system, attendant on the commencement of air-breathing by means of the lungs, which during the fœtal condition are quite inert.

From the foregoing meagre outline of its operations it appears that, in virtue of the powers conferred on it by its Creator, the animal organizer is a wonderful mechanist and fabricator. Nor less marvellous are its endowments as a chemist. It cannot, indeed, like the vegetable organizer, convert mere mineral elements into organic substances. But out of the products thus prepared for it by the latter, the former can elaborate compounds, both solid and liquid, marvellously complex in their constitution, to form any one of which is far beyond the range of human skill. Thus the influence over the material ultimates, exerted unconsciously by man as an organizer, far transcends any power he can exercise while acting consciously as a mind. Supply him with an unlimited quantity of any substances mineral or vegetable, which he might name, and out of them he could not, with all his art, form a single drop of milk, or of blood, of gastric juice or of bile, of lymph or of saliva, of sweat or of tear. Far less could he construct a bone or a muscle, a nerve or a brain.[1]

[1] Urea appears to be the only animal substance which has been produced artificially and it is merely organic refuse.

CHAPTER XIX.

METAMORPHOSIS.

The term Metamorphosis is employed in a different sense in vegetable, from what it is in animal physiology.

In the former, it denotes the changes, by which certain parts or organs of a plant become transformed into certain other parts or organs. Such transformations affect the stem and the leaves, but chiefly the latter. Thus the stem occasionally acquires a leaf-like expansion; or a portion of it may be changed into a thorn, spine, or tendril. The leaf-stalk may also become expanded into a sheath, partly or wholly embracing the stem from which it arises, or it may become flattened and extended into a leaf-like blade, from which the true leaves spring. So also the blade of the leaf itself may assume the form of a sheath, or a pitcher, or an utriculus, or a tendril. In like manner, the leaf-bud may, by arrested development, become a thorn, or on the other hand it may become transformed into a flower-bud; while the whole parts of a flower—the bracts, the sepals, the petals, the stamens, and the pistil, or rather its component carpels, may all be regarded as metamorphosed leaves. Examples not unfrequently occur, in which these several parts of the flower are replaced by true leaves; while the replacement of carpels and stamens by petals, which are merely modified leaves, is a familiar phenomenon. But these transformations are all partial, none of them affecting the entire organism.

In animal physiology, on the other hand, metamorphosis denotes that series of changes which an embryo undergoes in the course of its development after it has become capable of self-support. These changes usually involve the whole organism, not merely particular parts. They are not essentially distinct from those alterations which embryos brought to perfection within the egg undergo before being hatched. They differ only in the circumstance of their taking place after the embryo has left the egg, and become capable of self-sustenance; but they arrest more attention from their occurring before our eyes.

The phenomena of metamorphosis are confined to oviparous and ovoviviparous animals; while even among these they are far from being universal. Of the higher animals, the marsupials present the nearest approach to metamorphosis. The young marsupial, on first leaving the womb, is very imperfect, but it nevertheless bears a general resemblance to its parent. The limbs, indeed, are quite rudimentary, but they are present, and further development is accomplished almost entirely by growth. There is here, therefore, no true metamorphosis, which always involves the fabrication of new parts. In every case, therefore, where metamorphosis occurs, there is a certain amount of dissimilarity between the parent and the offspring when it first leaves the egg; and in many cases this dissimilarity is extreme, so extreme, indeed, that in some instances the offspring has been long regarded as an entirely different animal from the parent.

The highest animals in which true metamorphosis has been detected are the batrachian reptiles, the frogs, newts, &c. When the young frog first leaves the egg, its alimentary system is quite rudimentary. Most of the interior is occupied by what remains of the yolk of the egg, which for a time continues to supply materials for further development. The head, proportionally large,

appears split on the lower surface, each half projecting so as to form an instrument of attachment to surrounding objects. There is yet no trace of eyes or ears, nor have any organs of respiration yet appeared—that function being performed through the skin. The body is prolonged into a short tail with a membranous fringe. These features gradually change. At the end of about four days the head has become thimble-shaped, and nearly as long as the body; the mouth has acquired a pair of soft lips; eyes, ears, and nostrils have begun to appear; a deep groove separates the head from the now almost spherical belly, whence spring a pair of gill-covers with little branching gills; while the tail has so increased as to be as large as the body. Ere long the lips become horny, forming a sort of beak, fitted to peck vegetable food, and the intestine, now more fully formed and much lengthened, becomes spirally coiled; the tail is still further increased both in length and breadth, and the creature is now a tadpole.

During these changes the respiratory apparatus has been much altered. At first the skin was the only organ of respiration; the function was next performed by a pair of small, branching gills attached to the gill-covers; then these last become more closely united to the belly, the branching gills disappear, while there are formed, in recesses on either side of the neck, new and more complex gills, arranged in tufts and fastened to a solid frame composed of cartilaginous arches. Thus, although the mode of respiration continues all the while aquatic, the instrumental means are rapidly changed—a circumstance the more remarkable, seeing both the means and the mode of respiration are soon to undergo a more complete alteration.

The tadpole is at first destitute of limbs, and swims solely by the action of its powerful tail. It in all respects

resembles a fish, breathing by gills; and a fish it would be deemed, did it undergo no ulterior change. If kept in the dark it may be preserved in this condition for a long period, without entering upon its further development.

On being freely exposed to light, the tadpole in due time becomes gradually prepared for an entire change in its manner of life and outward aspect. It has to alter its mode of respiration from aquatic to atmospheric, and its diet from vegetable to animal. The tufted gills with their gill-covers gradually disappear; subsequently their supports of cartilage and bone—the whole apparatus, in short, appropriate to aquatic respiration—are by degrees absorbed, till not a trace of them remains. Meanwhile the lungs, hitherto rudimentary and solid, have grown and expanded; the pulmonary vessels have increased in number and diameter, the branchial vessels having simultaneously contracted. The respiratory organs have thus become those of an air-breathing animal.

During the progress of these changes, the mouth has enlarged in size and gape; the horny lips are replaced by teeth growing from the palate; the intestine has become shortened and of variable diameter; while the belly, formerly round, is now lank and slender. The limbs have likewise been in course of formation. They at first appear as mere projections under the skin, and are attached to the adjacent structure only by nerves and blood-vessels. The gradual development of the hip and shoulder-bones enlarges the projections, and eventually the other parts of the four limbs make their appearance, and attain their full size. Simultaneously with the development of the limbs, the tail begins to be absorbed, and the absorption continues till the entire member, with its skin, muscles, nerves, bones, and blood-vessels disappears—the whole of its substance being applied to the nourishment of the

other parts of the body. The metamorphosis is now complete; the fish has become an amphibious reptile—the tadpole a frog.

The changes involved in the metamorphosis of the other animals belonging to this class are less extensive and remarkable, and it is therefore needless to enter into details.

Among fishes, metamorphosis presents itself under a modified form in the case of the salmon, whose two preceding stages of par and grilse are now well recognised; but those stages involve changes of external appearance alone. A more decided metamorphosis occurs in the case of the lamprey, of which the rudimentary fish called the ammocetis has been ascertained to be the larva. In this case the alterations undergone in passing from the larval to the perfect form, are confined to the mouth, the foremost portions of the digestive tube, and the bones and muscles connected with the respiratory organs. It is expected, however, that other instances of metamorphosis may yet be found among the members of this class.

Examples of metamorphosis occur among the mollusks. The young of the sea-slug, for instance, on emerging from the egg, is provided with a shell. To its foot, as yet imperfectly developed, is attached a horny plate, which serves as a movable lid, by which the shell is opened and closed. Above the mouth is a double collar with ciliated edges, which acts as a swimming organ, and which the animal folds and unfolds at will. While it inhabits the shell, its digestive apparatus and liver resemble those of mollusks in general. Detaching itself in due time from the shell, it casts off the horny plate from its foot, which now becomes its chief organ of locomotion, and it loses the ciliated collars which previously served for that purpose. The body becomes elongated, and acquires branchial appendages on the back. The

intestine is lengthened backwards, increases rapidly in size, and sends out branches into every part of the body. The animal thus ultimately becomes a plebenterate naked mollusk.

In the Teredo, again, metamorphosis presents itself under a different aspect. On leaving the egg, the young Teredo, as already mentioned, is a ciliated animalcule nearly spherical in form, which by means of its cilia swims very actively. At the end of about thirty-six hours, the outer skin opens, and losing its vibratile cilia becomes encrusted with carbonate of lime. It is thus converted into a shell, whose form is first oval, then triangular, and lastly almost spherical. In place of the original cilia, the animal acquires a new locomotive organ, in the shape of a collar with a ciliated fringe. This organ is capable of being expanded or retracted within the shell; its action resembles that of the wheels of the rotifers, and it enables the animal to swim as actively as at first. Ere long there is added another locomotive organ, in the shape of a fleshy foot like a long flexible tongue, which the animal can put forth or withdraw at pleasure, and by means of which it can creep along any surface, however smooth or however highly inclined. The larva is also endowed with organs of hearing and sight; and during this stage of its existence the teredo displays great activity, while by its organs of sense it is placed in enjoyable relation with the external world.

Ere long it proceeds to undergo its last metamorphosis, and to form for itself a burrow. For this purpose it selects a substance which it can easily perforate, by preference a piece of wood, into which it may bore for itself a hole, that shall exactly fit the now altered form of its shell. This last has been lengthened into a long cylinder open at both ends, and has acquired at its anterior extremity a boring apparatus, consisting of two movable

valves, by means of which it first penetrates the timber. Between these valves lurks a small proboscis, by which the animal fastens itself, and on which it turns as on a centre-bit, so bringing the rough edges of its shell into play as a rasp for grating the wood. In this manner the burrow which it forms becomes perfectly cylindrical. The body of the animal soon becomes elongated into the shape of a worm, and though at first minute, it gradually grows until it may attain a length of about a foot, and a diameter of a half or three-quarters of an inch. The hinder end of the shell, which alone projects slightly from the burrow, is guarded by two lids that open to admit of the protrusion of two tubular organs, closing again when they are withdrawn. These two tubes, which are of unequal length, form the sole means of communication with the outer world, which now remain to the teredo. Its organs of sight, of hearing, and locomotion have disappeared, having become altogether useless, owing to the change in the animal's mode of life. Of the two tubes, one serves to draw in the sea-water, the other for its discharge. The water, charged partly with air and partly with nourishment, conveys the air to the respiratory organs situated near the posterior extremity, the food to an orifice at the anterior extremity which serves as a mouth, and is buried deep in the burrow. Thus, instead of being raised in the scale of being by its last metamorphosis, the teredo is lowered, its only gain being the development of the reproductive organs. Deprived of sight and hearing, and of all powers of locomotion save the capability of turning within its shell, and of turning the shell within the burrow, which it enlarges as it grows, its mode of existence thenceforward approaches more nearly to vegetable than to animal life.

The metamorphosis of the barnacles presents somewhat similar phenomena. The larva, about a tenth of an inch

long, inhabits a minute bivalve shell, resembling that of a mussel and opening along its whole length. It is provided with two sorts of limbs. In front are a comparatively large and strong pair, each furnished with a sucker and hooks, which are used as instruments of attachment. Behind there are six pairs of swimming organs, so connected as to act in concert and strike the water forcibly. The tail, composed of two joints and terminating in four bristles, is also used as a locomotive organ. These appliances enable the animal to advance through the water by sudden jerks. The larva is also furnished with pedunculated eyes. On undergoing their metamorphosis, which they do by casting off their integuments, the larvæ are found to be converted into young barnacles, firmly fixed to one spot. Their peculiarly constructed shells with their lids are rapidly formed, and their ciliated arms begin to play; but they have lost all their locomotive organs, as well as their eyes, these being no longer of any use.

The lerneans, or fish-lice, in the course of their metamorphoses, are first raised and then lowered in the scale of being. The larva primarily presents a crustacean type. It has eyes, and swims by means of a pair of feet, each terminating in a tuft of filaments. In the second stage, it has acquired in front three pairs of feet adapted for swimming, and a tail which also acts as a propeller. Thus far the metamorphosis has had an elevating tendency, and the animal roams freely in search of a fish on which it may fasten itself as a parasite.

Before assuming its parasitical and final state of existence, it undergoes another metamorphosis. The female, greatly increased in size, has one pair of her front set of limbs curved inwards and united at their extremities, terminating in a sharp-pointed projection, which she plunges into the tissues of the fish whereon she settles.

Another pair, reduced to mere hooklets, serve also as means of attachment, especially for the mouth, which has become adapted for suction. All the other members and the eyes have disappeared, and the body, much enlarged, seems to contain nothing but the stomach and ovaries, which become largely developed and full of eggs. In this state she remains the rest of her life as a parasite, drawing her whole nourishment from the fish on which she has fastened. The male, less altered in appearance, but two or three hundred times smaller than the female, becomes a parasite on his spouse for the rest of his days.

Among the crustaceans, metamorphosis is of rather frequent occurrence. For example, the common crab, on leaving the egg, presents a most peculiar appearance, and its larva was up to a late date regarded as a totally distinct animal, under the name of zoe. Its hemispherical body is surmounted by a long pointed horn curved backwards; while a similar but thinner long horn, curved in the same direction, projects downwards from the lower surface of the head. The eyes are sessile on the forehead and very conspicuous. The tail is jointed and longer than the body, the terminal joint being crescent-shaped and armed with long spines. The two last pair of feet are furnished with cilia and adapted for swimming, the others are scarcely discernible. In this, the zoe-stage of its existence, the creature swims freely, the tail acting as a propeller, and the ciliated feet as fins.

The first metamorphosis produces a complete change in the creature's appearance; and in this stage also it was long regarded as a distinct animal, under the name of megalopa. The body has become compressed, the horns have disappeared both from the back and head, while the region of the head and thorax have become rounded. The tail, still about as long as the body, has been flattened and furnished with three pairs of small lateral appendages,

amply tufted with hairs. The eyes are no longer sessile, but pedunculated. A pair of jointed antennæ project from the forehead, and there is a small pointed projection in the centre between them. The claws have become developed from the thorax, and four pairs of jointed legs appear at the posterior part of the body. The locomotive organs are thus equally adapted for swimming or crawling.

After the next metamorphosis, the creature assumes the form of the perfect crab. The tail has almost disappeared; the four pairs of feet and the claws have become approximated; the antennæ are shortened, and the sharp projection between them has dwindled into a rounded stump. The passage from the zoe to the perfect stage is through gradual transitions, accomplished by successive moultings. The perfect crab-form is attained while the animal is yet very small, and the subsequent moultings increase the size, but do not appreciably alter the form of the animal.

It is in the case of insects that metamorphosis presents the most interesting phenomena, and has excited the greatest amount of attention among naturalists. After leaving the egg, an insect generally passes through three distinct stages of existence. It is first a larva, then a pupa, and lastly it becomes an imago or perfect insect, like its parent, from which, in its other stages, it differs more or less. There are, however, considerable varieties in insect metamorphoses, according as they are more or less complete. The butterflies furnish examples of the most complete sort of metamorphosis; and the tortoise-shell butterfly may be selected for illustration, because of the curious provision made for the suspension of the pupa.

The eggs of this insect are deposited on the common nettle, the leaves of which furnish food to the larva.

When first hatched, the caterpillar is very minute, but it eats voraciously, and casting its skin several times, it rapidly attains a considerable size. During these successive moults, the aspect of the grub alters very little, it merely increases in dimensions. When fully grown, it is dark in colour and bristly with tufted hairs, about an inch and a quarter long, and a quarter of an inch in diameter. Its cylindrical body consists of twelve nearly similar rings. It has eight pairs of feet, of which the three pairs in front are horny, conical, jointed, and armed with little hooks at the extremities. The rest are membranous, resembling tubercles with truncated ends, fringed with a circle of hooklets. The latter set can be pushed out and withdrawn, as also turned in every direction. The caterpillar breathes through a series of little apertures arranged along both sides of the body, and extending over ten of the segments. The head is smaller than the other segments of the body. It has six simple and separate eyes. The mouth is armed with a pair of horny mandibles playing horizontally, in addition to a pair of horny jaws playing in the same direction, and partly covered by a pair of lips opening vertically; an apparatus well adapted to chew the leaves of the nettle, on which the grub feeds. Near the mouth is also placed a long tubular organ, with a minute perforation for the emission of the gum, which, immediately on its exposure to the air, stiffens into silk.

This spinning apparatus is brought into requisition when the larva prepares to pass into the pupa stage. Selecting a secure spot, and a horizontal surface whence it may easily suspend itself, it proceeds to form a small button of silk. This it does by first touching the surface with the point of its spinning tube, then turning its head to the other side, and simultaneously drawing out a thread of silk, it again touches the surface to which it glues

the thread, leaving it, however, to hang a little loosely, so as to form a small festoon. This operation it repeats again and again, till the fastenings of the thread form a complete circle, the festoons crossing each other in the centre. The button having been thus finished, the caterpillar, turning its tail towards it, thrusts into it the last pair of its membranous feet, when the circle of hooklets, with which these are fringed, becomes entangled in the silk. Thus anchored by the tail, the grub swings itself into the air, and hangs with its head downwards.

It has now to perform the difficult task of casting its skin while thus suspended, without losing hold of the silk; and this notwithstanding it has to part with the hooklets by which it is anchored, these being fastened to the skin which is to be discarded. Having by violent exertions made a rent in its integuments, the enclosed pupa forces itself through the breach, and by successive contractions and dilatations it pushes backwards from the head towards the tail, the torn skin, which is thus compressed into folds, that hinder the rent from extending quite to the extremity. The pupa has next to extricate its tail from the old skin, and push it up towards the silk, while still maintaining its hold on the slough for support. This last it does by grasping the cast skin between two of its contiguous rings, and these being extensile, it is thus enabled, while freeing its tail from the slough, to stretch it up till it reach the silk. The tail of the pupa, being provided with numerous hooklets, attaches itself by their means to the silk; so that being thus once more securely anchored to the button, the pupa again swings itself head downwards, and wholly disengaged from the moulted skin. Instinct, however, urges it to proceed still further, and to remove the slough entirely from the silk button. It first, by various contortions of its body, imparts to the slough an oscillatory motion. The pupa then, giving

itself a sudden jerk, begins to whirl rapidly. This motion increases the swing of the slough, and also gives greater tension to the silk, which thus ultimately becomes disengaged from the hooklets of the cast skin, and allows it to drop.

The pupa now hangs freely and alone. It is altogether unlike the caterpillar from which it proceeded. The skin is dense, horny, and varnished with a gummy substance, which exudes during the metamorphosis and quickly dries. The body is thicker and shorter than before, and exhibits two principal segments, of which only the hinder is composed of rings. The anterior portion has two horn-like projections in front and several others smaller at the sides; but it is otherwise apparently destitute of members, shows no distinction between head and thorax, and is without means of nutrition.

Within this case, which, owing to its gummy varnish, appears as if it had been dusted with bronze powder, the further development of the insect is carried on till it attain perfection. This end accomplished, the case is rent asunder, and forth comes the perfect butterfly in all its glory; the four wings being painted with brilliant colours, which have at first a beautiful freshness, subsequently impaired by the effects of wind and weather.

The butterfly is exceedingly different both in structure and appearance from the original grub. It has a distinct head, thorax, and abdomen. The head is proportionally small, and from its front proceed two long, club-shaped, horny, and jointed antennæ, of which the grub showed no trace. To the simple eyes, which still remain, are added a pair of large compound eyes occupying the sides of the head. The character of the mouth is quite altered: being no longer required for chewing, it is adapted for suction. The mandibles and lips of the grub are hardly traceable: but the jaws have been immensely lengthened; their

horny tissue has been replaced by flexor and extensor muscles; they are penetrated by nerves and air-tubes, and each is deeply grooved on its inner surface; so that, united together, they form a tubular proboscis twice as long as the insect's body. This instrument, popularly known as the butterfly's tongue, it usually keeps closely wound up into a spiral; but it can at pleasure unroll it, and dip it into the most deeply seated nectaries of flowers, thence to suck up the juices on which alone the insect now subsists. Attached to the under part of the thorax, the butterfly has six legs, corresponding to the six horny feet of the grub, but most dissimilar in structure and aspect. The latter were short and thick; whereas the legs of the fly are long and slender, consisting of five distinct parts, and terminating in a tarsus composed of five joints and two hooks. The four wings are fastened in pairs on either side of the back of the thorax, each united to the solid base by a chain of horny pieces linked by strong tendons, and furnished with powerful muscles, adapted to give the needful force and suppleness to the motion of the wings during flight. From the base of each wing arise four main divergent nervures, which, ramifying over the whole wing, support its membranes as on a frame. These nervures and their branches are hollow, admitting air to circulate through them. Two transparent membranes, firmly united, cover the upper and under surfaces of the frame formed by the nervures, and in these membranes are implanted, somewhat in the manner of a bird's feathers, the tiny scales to which the wings owe their colour and adornment. The abdomen of the butterfly, consisting of seven rings, corresponds to the hinder part of the caterpillar's body, which has undergone little change beyond the loss of its membranous feet.

These alterations of external form, which the butterfly undergoes in passing from the larval to the perfect stage

of its existence, are accompanied by corresponding internal changes affecting the digestive, the circulatory, the respiratory, and the nervous systems; all of which are subjected to very considerable modifications. To these are added in the perfect insect the reproductive organs, of which no trace can be found in the grub.

Although the metamorphoses, in the case of butterflies and insects generally, appear to be accomplished by sudden transitions from the grub to the pupa stage, and from the latter to that of the perfect insect, it is not so in reality. Each moult of the caterpillar advances the development a little further; and if, before the last moult, the skin be carefully removed, the pupa will be found ready formed underneath it. So also if the pupa-case be opened in different specimens from time to time, it will be found that the perfect insect is in the course of being formed within it by slow degrees. During this gradual development, there is not only a distinct fabrication of new parts, such as the antennæ, the compound eyes, the legs, the wings, and the reproductive organs of the perfect insect; but there is an obliteration of those which have become useless, such as the spinning apparatus and organs for secreting the gum from which the silk is formed in the caterpillar, and the membranous feet which were attached to its hinder part. Certain of the nervous ganglia of the grub become fused together, and certain others entirely disappear in the butterfly. There is thus unmaking as well as making, and alteration as well as growth of certain parts.

Still more interesting than those of the butterfly, are the metamorphoses of the gnat, for here the larva and the insect inhabit different elements—the former being aquatic in its habits, and swimming almost constantly near the surface of the water. The eggs of this fly somewhat resemble a sugar-loaf in shape, only they are

rounded at the thicker end, and have a minute knob at the smaller extremity. The round end is furnished with a lid, which opens to allow the larva to escape when it is ready to be hatched. The eggs are deposited in the water with the round end downwards, and to enable them to float on the surface without danger of sinking, a curious contrivance is adopted. Each egg is coated with a glutinous varnish, so that, on their being laid side by side, they adhere together and form a compact mass. But in depositing them, the gnat, by a little dexterous management with her hind legs, contrives so to arrange her eggs as to mould them into a tiny boat, raised at the prow and stern much like a Thames wherry. This boat is so admirably constructed that it rides on the surface of the water, even in the roughest weather, without danger of sinking, and is therefore a perfect life-boat.

When the larva is ready to be hatched, the lid at the lower end of the egg opens for its exit, and the grub comes forth head downwards; a position which it maintains during the whole of the larval stage of its existence. This grub is semitransparent, in colour whitish, and in form somewhat like a minute shrimp. Its breathing organs are not arranged along the sides as in land caterpillars, but an air-tube rises at an angle from the second last ring of the body quite to the surface of the water. Both this tube and the tip of the tail terminate in a set of leaflets and tufts of hair, which unite to form a sort of funnel, and are anointed with oil to repel the water. These funnels act as floats, serving to maintain the grub at the surface of the water; they are closed when it wishes to descend, and expanded when it desires to rise again—a bubble of air being entangled in the hairs of the air-tube when the animal dives.

On attaining its full size, which it does after repeated moults, the grub is about half an inch in length, and when

magnified presents rather an ungainly aspect, wholly unlike that of its parent fly. The head, proportionally large, is furnished with two ciliated organs, designed to convey by their vibrations food to the mouth. The thorax, still larger than the head, and somewhat octagonal in shape, is armed with tufts of hairs ; and similar tufts spring from each of the rings of which the abdomen is composed.

On passing into the pupa-stage, which it does by another moult, the creature is found to be much altered in aspect, as well as in the position it maintains. The head and thorax appear as if rolled together into one mass, within which the lineaments of the perfect insect may be traced. The abdomen remains little altered in appearance, but reversed in position, being now turned downwards and employed merely as a swimming organ, the air tube having disappeared. The respiratory apparatus has been transferred to the back of the thorax, which is now the part nearest the surface of the water. It consists of two air-tubes rising from the thorax above the water, so as freely to admit air to the internal air-channels. The design of this change of position is to admit of the escape of the perfect gnat from the pupa-case, without being submerged. When the time for this escape arrives the pupa becomes lighter, and the back of the thorax rises fairly out of the water. It soon dries and splits open, forming a sort of floating barge, whence the perfect fly springs at once into the air, without wetting any part of its delicate frame.

One other insect invites special notice, from its presenting the peculiarity of an additional stage in its metamorphoses, antecedent to that of the grub. The *Ophionurus*, one of the *Pteromalidæ* belonging to the hymenopterous family, deposits her egg in the inside of those of the *Rhynchites betuleti*, a small beetle infesting the vine. When it first leaves the egg, the *Ophionurus* is a

transparent animalcule nearly homogeneous in structure, divided posteriorly into a few segments armed with bristles, and having a long tail which it vigorously whisks. Within this first form is slowly developed a grub, which escapes by rupturing the skin, much in the same manner as the perfect insect escapes from the pupa-case. This grub, after successive moults, passes into the pupa-stage, whence it ultimately emerges as a perfect fly.

The phenomena of metamorphosis among insects present numerous other varieties and modifications, the metamorphoses in some cases being incomplete, and the alterations of form accompanying them inconspicuous; but the foregoing examples are sufficient to indicate the general nature of the process as it presents itself in this tribe. Among the classes of animals lower in the scale, the phenomena of metamorphosis become more or less involved with those of fertile nurse-forms, and will be more advantageously considered in connection with these. The instances which occur of metamorphosis pure and simple are not so diverse in character from those which have been already noticed, as to render it needful to cite them in detail.

The most striking feature in animal metamorphosis generally is the greatness of the change in both the external and internal characters of the organism which it involves. The gradual conversion of one species of animal into another, as of an ass into a horse, or even of one genus into another, as of a hare into a dog, would not involve alterations of structure so great as those which are thus embraced in the life-history of one and the same individual being.

CHAPTER XX.

FERTILE NURSE-FORMS AND PARTHENOGENESIS.

The phenomena of fertile nurse-forms are connected, on the one hand, with those of simple metamorphosis; on the other, with those of concurrent reproduction. In some cases, indeed, the one set of phenomena are so blended with the other that it is difficult to draw the exact line of demarcation. By a fertile nurse-form is to be understood an organism which becomes fertile without ever attaining, or at least before having attained, the perfect form due to its species. Its fertility may consist in its being endowed either with the sexual generative faculty, or simply with the power of individual multiplication, in one or other of its modes—as by fission or gemmation. In simple metamorphosis, it is one and the same individual organism that passes through all the stages, from the form which it wears on leaving the egg, to that which it assumes on attaining the perfection belonging to its species; but in the case of a fertile nurse-form, it is in general only those forms which are produced by the nurse that ever attain the perfect specific type. So likewise in simple concurrent reproduction, it is one and the same organism that exerts both the power of individual multiplication and the faculty of sexual generation; whereas, in the case of fertile nurse-forms, it is seldom they possess both, but if the nurse be endowed with the one, its offspring will be endowed with the other. Nevertheless, instances do occur in which a nurse, after having exerted

the power of individual multiplication, may itself acquire that of sexual generation. On the other hand, it sometimes happens that there are more than one fertile nurse-forms, either similar or diverse, intervening between the organism produced from the egg, and that which ultimately attains the perfect form of the species. These phenomena, and the various gradations of difference by which they may be distinguished, will be best understood by citing examples.

In the vegetable kingdom, the most conspicuous example is furnished by the ferns and horse-tails. In both of these families, the spores produced by the perfect plant do not result from any procreative act, but are developed simply by vegetative growth. In the ferns, these spores are formed in spore-sacs, or sporanges, on the lower side of the leaf or along its margin. In the horse-tails, the sporanges are borne upon a spike at the end of the stalk. These spores are of the nature of bulbs. When one of them is dropped into the soil, the plant which springs from it never itself attains the perfect form of fern or horse-tail. It is termed a prothallium, and is wholly unlike the parental plant, being very inferior to it both in size and development. Nevertheless, it is on this prothallium that the true generative organs are produced. These consist of two sorts of vesicles—the one named antheridia, which are filled with spermatozoids; the other named archegonia, and containing germ-cells. From the conjunction of the spermatozoid with the germ-cell, there results a new embryo, which alone becomes developed into a perfect plant, the prothallium withering away. Thus the prothallium performs the function of a fertile nurse-form in relation to the perfect fern or horse-tail. In this case, it is the nurse that is endowed with the sexual generative faculty; while the perfect plant is restricted to individual multiplication by buds.

It will be perceived that the phenomena here are quite distinct from those of concurrent reproduction, as they occur in such a plant as the potato. In that case, it is one and the same plant that produces the tubers and the seeds; and whether the tuber be planted or the seed be sown, the result will be another potato-plant like its progenitor. The case of the potato would resemble that of the fern or horse-tail only if, on the tuber's being planted, there should arise a diminutive plant bearing fertile flowers but no tubers; and on the seed's being sown, there should arise a more stately plant quite unlike the other, and bearing tubers but no flowers. The case of the fern and horse-tail involves a metamorphosis—not, however, of the individual organism, but of the species—one form being borne by the nurse, the other by the perfect plant. This, again, is a distinct phenomenon from simple metamorphosis, in which the changes of form are always undergone by one and the same individual organism.

Turning to the animal kingdom, the case of certain of the Echinoderms claims the first attention; for it presents a connecting link between the phenomena of the fertile nurse-form and simple metamorphosis. Both the Ophiurus and the Echinus furnish examples. The forms first assumed by these creatures, on their coming forth from the egg, are so unlike those which they ultimately acquire, that they were long regarded as distinct animals, or rather animalcules, for they are of microscopic size. The young ophiurus was termed the Pluteus, or Easel-animalcule, from its likeness to a painter's easel. On first leaving the egg, this creature is spherical; but it gradually becomes elongated, and acquires an internal calcareous frame-work or skeleton, which ere long puts forth long slender branches. These afford support to the body and arms of the pluteus, on the organism's gradually becoming metamorphosed into that form. It is then only about two-

fifths of an inch in length, and when magnified presents a most peculiar aspect.

The body of the pluteus is somewhat conical, the apex of the cone being fringed with a circle of cilia. From the sides, and nearer the apex than the base, proceed downwards two long divergent arms, constituting the outermost pair. Immediately under these, and also stretching downwards, are two pairs of shorter arms, the one pair behind, and the other in front of the long arms. Still lower down are another short pair, nearly parallel to each other, and lying in the same plane with the first long pair. The whole eight arms are fringed with cilia, and supported by the internal calcareous skeleton above-mentioned, which, having its origin in the interior of the body, sends out branches to sustain the soft parts of the arms. The whole animal is transparent, and in its interior can be seen the stomach and the gullet—the former being nearer the apex of the cone, the latter immediately under it and opening into the mouth, which is still lower down. Between the mouth and the base of the cone are a pair of small nervous ganglia, sending out filaments in various directions. In this stage of its existence the animal swims freely by means of its ciliated appendages.

This, which is the nurse-form of the species, does not itself become developed into a perfect starfish; but by gemmation it produces a new organism which, by growth and metamorphosis, becomes a starfish of the Ophiurus tribe. The first traces of this new organism make their appearance in the shape of certain sac-like appendages round the margin of the stomach, and along the edges of the gullet of the pluteus. These minute sacs soon become multiplied into several rows, which at first lie wholly within the body of the nurse-form. Ere long, acquiring greater development, they make their appearance outside, assuming a certain regularity of arrangement, and exhibiting

the rudiments of the star-form, the points whence the arms are to proceed becoming discernible. There next begins to be formed a calcareous crust, which has at first an arborescent appearance, and then gradually overspreads the entire surface of the newly formed echinoderm. The mouth of this infant organism is in a different position from that of the pluteus, being higher up and occupying the centre of the rudimentary star, which is still much smaller than the nurse-form on which it is in the course of being fabricated. But the star, gradually increasing in size, soon begins to put forth its fine long arms; whereupon the pluteus perishes, leaving no part of itself but its stomach to enter into the composition of the ophiurus that has thus budded from its interior. This last in due time acquires reproductive organs, either male or female, destined to perform the function of sexual generation by spermatozoa and ova. There is here therefore a reverse arrangement from what subsists in the case of ferns and horse-tails. There it was the nurse that was endowed with the power of producing the perfect form by sexual generation, the perfect form producing the nurse by gemmation; here the nurse produces the perfect form by gemmation, while the perfect form reproduces the nurse by sexual generation. The latter arrangement is what prevails in the animal kingdom.

It will be observed that, in the case of the ophiurus, the phenomena are blended with those of simple metamorphosis and concurrent reproduction. Not only does the pluteus undergo a metamorphosis of its own, between its leaving the egg and its beginning to produce by gemmation the ophiurus, while the latter acquires its perfect condition also by a metamorphosis of its own; but seeing the stomach of the pluteus becomes that of the ophiurus, the primary individuality of the former is only partially, not altogether lost. It is this circumstance that renders

the case of the ophiurus transitional. It forms a connecting link, in which the phenomena of the fertile nurse-form are blended, on the one hand, with those of simple metamorphosis, and, on the other, with those of one and the same organism's possessing more than one mode of reproduction.

The phenomena in the case of the echinus are so similar, that it is needless to dwell upon them in detail. Prof. Owen has proposed to distinguish the peculiar mode of development above described by the term Metagenesis.

Among the Aphides, or plant lice, the phenomena of the fertile nurse-form are more isolated and decided. From the egg of this insect there comes forth a six-legged wingless organism, more analogous to a pupa than a grub; so that the larval stage may in this case be regarded as suppressed. This organism, however, is not a true pupa, seeing it does not itself pass by metamorphosis into a fly; but, after attaining by growth and successive moults a certain size, this immature aphis begins to bring forth a succession of other individuals exactly like itself, and this although it may have been kept perfectly isolated from the moment of its birth. The individual, thus hatched from the egg, may in this manner produce in succession from 50 to 100 individuals exactly resembling itself. But what is more remarkable, each of the individuals thus resulting from the original organism is capable of multiplying itself in a similar manner. And the third set are likewise endowed with the same faculty, which in some instances extends to the tenth series in descent from the original individual. So rapid is this multiplication and so vast in extent, that, according to estimates which have been carefully made, the first individual might, in the course of a summer, become multiplied into 4,000 billions, were all preserved alive and endowed with the average degree of fertility. This excessive multiplication, however, is

checked by the numerous enemies to which the aphides fall a prey.

These fertile organisms are all immature females, and such only are ever hatched from the egg of the aphis.[1] Their multiplication, however, takes place, not by eggs, but by small buds which grow on the imperfectly developed ovaries. These successively drop into a special cavity of the body, where they become developed into new individuals, exactly like their parent only of much smaller size; and they are born alive. This process continues all the summer months; but when the temperature declines towards autumn, the power of multiplication in this manner ceases, and the last brood, instead of exerting this faculty, become developed by metamorphosis into the perfect insect, some of them into perfect males producing spermatozoa, others into perfect females having fully developed ovaries filled with eggs. These propagate sexually in the usual manner. The female deposits her eggs on the plant whose leaves are to furnish food for her offspring; and it is not till the young leaves appear in spring that the eggs are hatched, when they produce imperfectly developed but fertile females as before. The perfect males and females, into which the last brood of the season becomes developed by metamorphosis, are generally winged; but this is not uniformly the case, some otherwise perfect males and females being wingless. In plate P. fig. 1, is given a representation of the aphis which infests the maple tree, *Aphis aceris*, magnified 75 diameters.

The immature females are in this case fertile nurse-forms in relation to the perfect insect. It is remarkable,

[1] M. Balbiani, having recently made a series of anatomical investigations of the wingless aphides, gives it as his opinion that they are ovoviparous self-impregnating hermaphrodites; but this view has not been as yet confirmed by any other observer.

in a theoretical point of view, that if, on the arrival of autumn, these nurse-forms be still kept at a summer heat, their power of individual multiplication and that of their offspring may be considerably prolonged—thus proving that a high temperature favours this sort of fertility. On the other hand, there have been recorded instances in which a nurse-form, after having by internal gemmation produced others like itself, instead of perishing, goes on to become itself developed by metamorphosis into a perfect female. Such cases, however, are exceptional. The fertile nurse-form of the aphis generally dies without ever becoming further developed; and it is only those of her offspring, which so long as they wear the nurse-form are not fertile, that undergo metamorphosis and become perfect insects. The exceptional case, however, is a connecting link between the fertile nurse and the individual organism possessing more than one mode of reproduction.

It will be observed that the nurse-form of the aphis produces by gemmation other individuals like itself. In the case now to be cited, the nurse-form produces by gemmation other individuals unlike itself. The Salpæ, a family of ascidians or tunicated mollusks, present themselves under two distinct and dissimilar forms—the one solitary, the other connected together in long chains. The solitary individual is the nurse-form, the chained individual the perfect form of the species. Each of the latter is hermaphrodite and produces a single impregnated egg, which is hatched in the interior of its body, so that the progeny comes forth alive. The offspring, however, is in both external appearance and internal structure quite unlike its parent. It has neither ova nor spermatozoa, but is furnished with a peculiar internal organ—the prolific stolon, which is in immediate vascular connection with the heart. This, which is the nurse-form of the animal, never itself becomes a perfect salpa; but it

produces a continued succession of such, by internal gemmation from its prolific stolon. These perfect salpæ are, like the others, brought forth alive, and are at first very small, but grow rapidly. They are born attached together in a double row, end to end, and remain so attached during the rest of their lives. They are united, however, not by any common integument, or other organic tie, but by special organs of attachment which vary in the different species. The chain of salpæ, when completed, separates itself from the nurse-form, and swims about as if it were a single animal. It is sometimes as much as two yards and a half long. In due time, each individual in the chain produces by sexual generation a young nurse-form, and so the cycle is repeated. It will be observed that in this case it is only the species that undergoes metamorphosis, and exhibits concurrent modes of reproduction. The two diverse forms, and the two distinct modes of reproduction, are always found each in different individuals, never both in one and the same.

The system of fertile nurse-forms prevails among the Medusæ, or jelly-fishes, presenting some remarkable features. In these animals the sexes are separate. The eggs, after impregnation, are carried about by the female in receptacles adapted to the purpose, until they are hatched, when there comes forth from each a small ovoidal larva covered with cilia, and having a slight depression on its anterior extremity. By the help of its cilia this larva swims about actively; but at the end of about forty-eight hours, it attaches itself by means of the little cup in front to some solid substance, such as a piece of sea-weed. Here the creature becomes fixed—the margin of the cup extending outwards to increase the firmness of its hold. The larva now undergoes metamorphosis, resulting in its conversion into a polyp. Its body becomes elongated, enlarging in diameter as it ascends.

In the centre of its rounded top an opening soon appears, and under it an internal cavity is formed. The cavity becomes a stomach, the opening a mouth, round the margin of which there grow little projections, that soon lengthen into tentacles, which, playing in the water, supply the animal with food. This polyp is the fertile nurse-form of the medusa. Ere long it begins to put forth buds from its sides; the circular disc, which forms its means of attachment, begins to spread itself over the surface of the supporting foreign body, and from this expansion there arise other buds. All these buds acquire by degrees the form of the first polyp, and then in their turn put forth other buds, which follow the same course. The nurse-form thus multiplies itself by external gemmation into a polypidom.

After the lapse of a considerable time, during which this multiplication is in progress, one of the polyps enlarges itself, particularly in length, so that it becomes nearly cylindrical. There soon appears under the circle of tentacles an annular constriction, which is followed by a second at a short distance down the stem, then by a third a little further down, and so on till the whole stem becomes divided into annular segments down to the footstalk, which, however, remains entire. These constrictions have been formed in preparation for the polyp's undergoing spontaneous fission. Each of the rings into which the stem has become divided gradually acquires, at its lower edge, a protruding margin, divided into eight festoons, whose partitioning projections gradually stretch outwards and become forked at their extremities. These projections, being arranged exactly over each other, give the polyp the appearance of its having acquired eight longitudinal ribs. The intervals between the rings now gradually widen; and the segments, though still united together at their centres, soon begin to manifest, by the

independent movements of their forked projections, their having acquired a certain amount of separate individuality. The segmentation ere long extends inwards, till the uppermost segment carrying the tenacles falls off. Then each of the other segments separates itself in succession, and swims away as an independent animal. It is not as yet, however, a perfect medusa; but in due time, by undergoing metamorphosis, it assumes that form, acquiring at the same time either male or female sexual organs. By means of these there are again produced impregnated ova, whence spring fresh nurse-forms that repeat the cycle of change.

There is, in this case, a curious combination of diverse phenomena. There is first the nurse-form undergoing a metamorphosis of its own. It then acquires a power of multiplying itself by external gemmation: all the forms thus produced exactly resembling itself, and the whole remaining in organic connection one with another, so as to constitute a compound organism. Then this last acquires, in one of its constituent members, a power of multiplication by fission; so that there are here two modes of multiplication concurrent in the same organism. The individuals resulting from this fission, however, are quite unlike their immediate parent the nurse-form, but by passing through a metamorphosis of their own they attain the perfect form of the species, and acquire the faculty of sexual generation. It is only certain species of medusæ that have these polyp nurse-forms; others undergo simple metamorphosis.

In Campanularia, the phenomena above described are nearly reversed—the perfect form of the animal being a compound polyp, and the nurse-form an isolated organism, much resembling a medusa. The latter is hatched from the egg while yet within the mother-polyp, and there goes through all the stages of its primary development,

being nourished by its remaining in connection with the polypidom. It is accordingly born alive, and in form resembles a very minute mushroom, the stem being replaced by a fleshy tubercle, and the margin of the lenticular top being fringed with a circle of pensile tentacles. Between these and the central tubercle there are disposed, on the lower surface of the disc, eight minute circular bodies supposed to be organs of sense.

This medusa-like organism swims about very actively for a time, in search of some fitting substance whereon to fix itself, and that may afford support to the new polypidom which it is destined to found. Having discovered the desired object, it attaches itself to it by means of its tubercle, and then the disc with its tentacles flattens down and adheres to the solid surface. The organism, however, still retains in its centre a cavity, wherein there soon appear granules which, growing and elongating upwards, become a straight hollow stem, that acquires externally a transparent horny sheath. Near the upper end of this stem there is formed ere long a bud, shaped like an inverted bell, having its mouth closed by a horny membrane. From the inner surface of this capsule the organic materials withdraw, and shrink into a conical bottom, at the top of which there soon appears a small opening, round whose margin tentacles begin to grow. The bud is thus converted into a polyp which, on its being completely developed, bursts through the horny lid of the capsule, and begins to ply its tentacles in search of food. Meanwhile the stem continues to grow and to put forth branches, which in their turn divide into other branches, that produce at their extremities bell-shaped buds, which eventually become developed into polyps like the first. The stem and its branches, like those of a plant, increase in thickness as they grow in height; thus acquiring strength to sustain the numerous polyps which

form the colony, and which are all in connection one with another, through the medium of the hollow stem and branches of the polypidom.

Thus the solitary medusa-like nurse-form has by gemmation produced a polyp, that, being endowed with the power of multiplying itself also by gemmation, has expanded into a polypidom, which, however, is itself only a second nurse-form. This last has yet to produce, likewise by gemmation, more perfect polyps, male and female, endowed with generative organs. At certain seasons there spring, from the axils of the branches of the polypidom, buds which, though at first resembling the others, soon assume a different appearance, and greatly exceed them in size. They are attached to the polypidom by foot-stalks, much shorter than the branches that support the other polyps. As they increase beyond those others in length more than in diameter, they acquire on reaching maturity a somewhat cylindrical shape. A branch from the hollow tube, constituting the core of the stem, forms the axis of this cylinder, and at its extremity there is developed a fresh polyp-mouth surrounded by tentacles, but smaller than the previously existing polyp-mouths. It is in the cylindrical capsule itself that the organs of reproduction are developed. In the male there are formed bundles of spermatozoa. These, on attaining maturity, are discharged into the water through the polyp-mouth of the capsule, which, having thus performed its function, immediately falls off from the polypidom, and perishes. The spermatozoa are imbibed by the polyp-mouth of the female capsule, which grows on the same polypidom with the male. The eggs contained in the female capsule, being thus impregnated, straightway begin to undergo primary development, the operation commencing with segmentation of the yolk, and following the same course as in other animals of this class. Each egg thus ripens into a medusa-like animalcule, and on acquiring its

tentacles and organs of sensation, this new organism issues forth alive from the polyp-mouth of the female capsule, which, as soon as the whole of the young brood have been thus discharged, falls off and perishes as did the male. The polypidom, however, with its other polyps, survives, and will in course of time produce a fresh generation of male and female polyps, which will go through the same course. The medusa-like offspring swim away, and if not devoured in the interval, each will become the founder of a new colony.

It will be perceived that in this case the first nurse-form produces by gemmation a second, which produces, also by gemmation, first a number of others like itself, and then perfect individuals of the species, endowed with the faculty of sexual generation.

The phenomena, in the case of the Sertularian polyps, so nearly resemble those of the Campanularia, as to render it unnecessary to enter into details. Examples of the phenomena of fertile nurse-forms might be multiplied from among animals lower in the scale than the polyps; but those already given are sufficient to convey a general notion of the nature of these phenomena. It is the less needful to cite more examples in this place, because others will have to be adduced in connection with the subject of parasitic life—fertile nurse-forms being prevalent among parasites.

Parthenogenesis is a somewhat different phenomenon from that of the fertile nurse-form. In the latter, it is always an immature form of its species that becomes fertile without sexual concourse; but in true parthenogenesis, it is always a perfect virgin female that becomes prolific. The phenomena are, nevertheless, intimately related, inasmuch as there is in both cases virgin fertility.

Parthenogenesis has been detected both in the vegetable and animal kingdoms.

Among plants, instances are said to have been observed in which the germ-cells of the Cœlebogyne, Cannabis, Mercurialis, Hemp, and Bryony, whence the pollen has been carefully excluded, have nevertheless become developed into fertile seeds.

Among animals, similar phenomena have been detected in certain of the crustaceans and insects. The cyclops and the daphnia, two genera belonging to the Entomostraca, furnish examples from the former class. In the female daphnia, or water-flea, there appears, towards autumn, within the back of the shell, a dark opaque mass, shaped like a saddle, whence it has been named the Ephippium. Embedded in this mass are two eggs, each incased in a dense horny covering, and contained in a capsule which opens like a bivalve shell. These are winter-eggs, and are always sexually impregnated. When hatched in spring, they give birth to perfect females, which, notwithstanding the entire absence of males at this season, begin to deposit eggs in a cavity situated between the back of the animal and the shell. In this receptacle these unimpregnated eggs, which are quite different in appearance from the ephippial impregnated eggs, undergo primary development; and when the mother casts her shell, the young brood at the same time escape, and throwing off the integuments of the egg, commence a separate existence. They are at first very small and imperfectly developed, but ere long arrive at maturity. The same female soon produces a second brood, followed by a succession of several others. The whole of the young animals, thus produced by parthenogenesis, are, during the summer months, perfect females, and each of them is capable, like its parent, of repeating the same reproductive process. Towards the approach of winter, however, the young broods, thus produced by parthenogenesis, are no longer females, but males which are

found only at this season. These impregnate the females then remaining alive, and the result is the formation in them of the ephippium, with its pair of impregnated winter eggs, which renew the same cycle of phenomena the following summer. There is here no nurse-form; but the perfect females perform first the same office as the nurse-forms of the aphides, and then the function of sexual generation.

There has recently been discovered a case which seems to be intermediate between that of the aphis and the daphnia. It is that of certain two-winged insects of the family Cecidomyia—more especially the *Miastor metraloas*, and the *Oligarces*. From the impregnated egg laid in August by the perfect female of these insects, there comes forth a grub, which, lurking under the bark of trees, feeds on the young bark and sap. This grub, however, does not itself undergo metamorphosis, but is a fertile nurse-form in a less advanced stage of development than that of the aphis. After the grub has attained a certain stage of growth, immediately under the skin, towards the hinder part of the body, there appear organs which seemingly correspond to the ovaries of a perfect insect. In these are elaborated eggs considerably smaller than those produced by the perfect females of the species, but otherwise differing little from them in appearance. From these grub-eggs there are developed other grubs, which are hatched inside of this nurse-form, and move about freely in her interior. Here they grow at the expense of their parent, whose tissues they successively devour, until they leave nothing but her skin, through which they ultimately gnaw their way—coming forth to feed and nourish themselves on the young bark of the tree, as did their parent. Like her also, each of them, on attaining a certain size, acquires ovarian organs, in which are elaborated after the same fashion similar eggs, whence

proceeds another brood of grubs, which follow the same course of devouring their parent, and gnawing their way through her skin. This process is repeated several times during the winter months, until the arrival of May, when the last broods produced by the then existing nurse-forms, instead of coming forth as grubs, remain within the skin of their parent, which thus becomes converted into a pupa-case. Here they undergo metamorphosis, after which, they come forth perfect flies, male and female. The females have regular ovaries, and produce true eggs, which are large in proportion to the size of the parent. These eggs are duly impregnated in August, and from each comes forth the first of the series of grub-nurse-forms to repeat the reproductive cycle. It will be perceived that this case, notwithstanding the fertile unimpregnated eggs are produced by successive nurse-forms, which are devoured by their own offspring, approaches more nearly to that of the daphnia than to that of the aphis; but it differs from the case of the fertility of unimpregnated eggs produced by a perfect female.[1]

As regards perfect insects, there are well authenticated instances of the occurrence among them of parthenogenesis as an occasional phenomenon. It has been observed among moths, butterflies, honey and humble-bees, wasps, ants, gall and cochineal insects. In the great majority of these cases, the progeny hatched from the unimpregnated eggs of the perfect female have been exclusively males. This is especially true of the unimpregnated eggs of the queen-bee, from which only drones ever come forth. This may be regarded as a sign of imperfection; for even when a queen-bee has been impregnated; if she be thereafter kept on spare diet and at a low temperature, her eggs will produce nothing but drones. As a general rule,

[1] *Popular Science Review*, April 1867.

the male among the invertebrata occupies a reverse position from what he holds among the vertebrata. Among the latter he is usually a more perfect organism than his mate. But among the invertebrata, the females are in most cases organically superior to the males, which are inferior both in size and general development, and often so dissimilar to the females in appearance that they might be mistaken for animals of a different species.[1] Hence the reproductive effort required to produce a male is, among the invertebrata, less than is needed for the production of a perfect female, or even of an imperfect female such as the neuter bee. It is only when the fecundity of the female has been lowered by deficient food or cold that she produces males; and the same effect results from the absence of impregnation.

Instances have nevertheless been recorded in which perfect female insects have been hatched from unimpregnated eggs, and even of such females having, in their turn, produced unimpregnated eggs, from which other perfect females have emerged; but from the unimpregnated eggs of this third generation of females only males have ever been hatched—so closing the series.[2] But the production of females from unimpregnated eggs is an exceptional case, and there are reasons for suspecting such

[1] Of this dissimilarity between the males and females of the same species, a curious example was observed by Mr. Wallace in his travels in the Eastern Archipelago, as occurring among the swallow-tailed butterflies. The females of *Papilio œnomaus* and *P. liris* are so like each other as to be scarcely distinguishable; but each differs remarkably from its own male, while the two males are also very dissimilar. Query—Had those two species been derived either from each other or from a common ancestor by an accumulation of small modifications, why should these have affected only the males, and why should each male differ so much from its own female?

[2] Mr. Richard Beck has recently obtained in one season, from a single unimpregnated female of a species of mite, three successive generations, without any males having been detected among the progeny. *Trans. Microscopical Society*, xiv. 30.

eggs to be more of the nature of bulbs, or deciduous buds, than true eggs. The reproductive bodies, in the case of the fertile nurse-forms of the aphis, are doubtless of the nature of bulbs, and it does not appear improbable that similar bulbs, where they are to be developed apart from the parent, may be for a while protected by a shell like that of an egg, and may thus be not easily distinguishable from true eggs. The difference between the impregnated and unimpregnated eggs of the daphnia goes far to confirm this view. But it may perhaps be more correct to regard all unimpregnated eggs which prove fertile, as holding a position intermediate between impregnated eggs and bulbs. That they do partake of the nature of the latter is proved by the limitation of their fertility, which never extends beyond a third generation, and generally terminates in the first by the exclusive production of males, whose intervention becomes indispensable to the perpetuation of the species. Reproduction by unimpregnated eggs may accordingly be regarded as a transitional mode, intermediate between gemmation and generation.

CHAPTER XXI.

PARASITIC LIFE.

Among the phenomena which present themselves to the study of the physiologist, none are more curious than those relating to parasitic life; it appears at first sight so strange that one set of organisms should seem destined to inhabit other living organisms, and draw from them the whole or a great part of their nourishment. This strangeness is aggravated when it is perceived that the parasite, in many cases, induces on its victim disease or death. There is here, however, a gradation by which the whole phenomena are linked together and subjected to a common law.

All living organisms whatever may be said to pass some portion of their existence as parasites. Regarding the sperm and germ elements as elementary organisms, these may be viewed as in every instance parasitical upon the organism in which they are found, so long as they draw from it their nourishment and grow at its expense. This first stage of parasitic life early ceases in the case of the higher algæ, and of fishes and other aquatic animals, in which the sperm and germ elements both become separated from the parents before they unite together. The parasitic condition is slightly prolonged in the case where the conjunction between sperm and germ takes place within the parental organism, and is still further prolonged where, after this conjunction, the embryo continues to subsist upon the parental organism for a certain

period of time. This happens with all viviparous animals, and to a greater or smaller extent with a large proportion of plants. It is a question for consideration, indeed, whether the sperm and germ elements, when they conjoin, do not, one or the other, become parasitic upon its mate —or whether they do not, by their union, originate a new individual, which, as a parasite, develops itself at the expense of both of the uniting elements, as often happens in the conjugation of similar cells.

In the case of most plants, after conjunction of the sperm with the germ element, the union with the parent is prolonged until the embryo attains a certain stage of development, and becomes enveloped in the integuments of the seed and embedded in the endosperm, where such exists. All the materials thus appropriated by the young organizer of the future plant are derived from its parent. In general, the connection with the parental organism ceases when the seed is fully ripe; but in certain plants, thence termed viviparous, it is still further prolonged. Thus in the Rhizophoraceæ, or Mangrove tribe, the seed germinates in the fruit while still attached to the tree, and sends out a long radical until it reaches the muddy soil in which the mangrove delights. It thus continues a parasitic life, deriving all its nourishment from its parent, till its root becomes firmly fixed in the ground, whence it may obtain food for itself; and not till then does the young plant detach itself from the parental tree.

Bulbs, conidia, gonidia, zoospores, and tetraspores are all parasites during the first stages of their existence, but cease from that mode of life on becoming detached from the parental organism. Adhering buds, however, continue parasitical till they die, or are forcibly removed.

In all these instances the young organism is parasitical upon its parent; but in the case of buds these may be transferred either to another individual of the same species

or to an individual of a different species or even genus. By this method a new sort of parasitic life becomes established—that of one organism growing at the expense of another belonging to a species different from itself; and it is in this restricted sense that the term 'parasite' is generally applied. Certain plants have the power of thus grafting themselves naturally on others, upon which they spend the remainder of their existence as parasites. Of these there are three sorts. The first kind begin their development from the seed by germinating in the ground near the plant they are about to attack, and their roots seek out those of their victim, penetrate them, and establish themselves upon them as parasites. Some of these, as the *Orobanchaceæ*, or Broom-rapes, draw all their nourishment from the plants to whose roots they adhere; while others, as *Thesium*, *Striga*, *Melampyrum*, and *Rhinanthus*, draw only part of their nourishment in this manner, retaining some roots that partially absorb food from the soil. The second kind also in the first instance germinate in the ground, but subsequently coil themselves round adjacent plants, and send adventitious roots into their rind; and when they have thus established themselves as parasites, their attachment to the soil dies away. Thus *Cuscuta*, a genus belonging to the Convolvulus tribe, has this habit, and is very destructive to the plants (chiefly flax and clover) which it attacks. A slight variation from this case is presented by the *Sipó Matador*, or Murderer Liana, which destroys its supporting tree by a species of strangulation—retaining all the while its own roots in the soil, but ultimately perishing by the fall of the tree on which it has climbed.[1] The third kind do not germinate in the ground, but while yet in the state of seed establish themselves at once as parasites on the

[1] A vivid description of this parasite is given by Mr. Bates in his *Natural History of the River Amazon*, i. 53.

stems of other plants. Of this sort are the order *Loranthaceæ*, of which the *Viscum*, or Mistletoe, is a genus. This plant attaches itself to the young shoots of trees (chiefly those of the apple, thorn, oak, elm, willow, and lime), by means of the viscid pulp of its fruit. The radical of the embryo, on its germinating, becomes an expanded disc, concave on the upper side, and by this, as by a sucker, it cleaves to the bark. It then puts forth, from the centre of the disc, fine rootlets, which penetrate through the bark and liber into the cambium, whence they absorb the juices of the tree. The mistletoe thus becomes exactly like a bud transferred from one tree to another. In the case of the Myzodendron, another genus of the same order, the attachment is formed by long feathered processes, that coil round the branches on which they settle.[1] The orders *Balanophoraceæ*, *Cytinaceæ*, and *Rafflesiaceæ* become affixed to the roots of other plants, and grow parasitically upon them ; but the mode in which they attach themselves has not been ascertained. All the above-mentioned parasites are flowering plants.

In none of these cases, except that of the *Cuscutæ* and the Murderer Liana, is the growth of the parasite inconsistent with the healthy growth of the plant to which it attaches itself. It only partakes of the nourishment furnished by the stock in the manner of a graft. But it is different with another sort of parasites, the

[1] The *Ficus Indica*, or Banyan tree, and some others of the fig genus, present a variation from this sort of parasite, inasmuch as they do not strike their roots into the tree which lends them support, nor draw from it any nourishment. The seeds of the fig are dropped by birds into the axils of the leaves of certain palm trees, or into some cleft or bifurcation in some other species of tree, and, there germinating, send down roots to the ground, into which they strike and fasten themselves. These roots enlarge and multiply to an immense extent, so as to cover a large area, which the fig tree subsequently overshadows with its branches and leaves. In general, however, the original supporting tree is not destroyed by this process, but presents the appearance of growing out of the midst of the fig tree.

Entophyta. These all belong either to the lower algæ or to the fungi. Their spores generally attach themselves to plants, or parts of plants, which have already become weakened or diseased through adverse atmospheric influences, deficient nourishment, or over-stimulating manures; and when once they germinate, they, by feeding on the juices of the plant and by their own rapid multiplication, aggravate and spread the diseased condition, and ultimately kill the plant which they infest. In some instances also the spores may themselves, by irritation, induce a diseased condition of their victim favourable to their generation, so that the disease appears to become epidemic.

It is not a little remarkable that plants so low in the scale as even the desmids should be a prey to parasites of this kind. The one which attacks them is the *Chytridium*, a genus of the confervoid algæ, whose spores fix themselves on the integuments of the desmids, and on germinating penetrate into the cavity of the frustule with their delicate fibres, which absorb the cell-contents, and leave nothing but the empty shell. The most destructive vegetable parasites affecting other plants are genera of the orders *Sphœriaceœ* and *Botrytaceœ*, belonging to the fungi. The ergot of rye, the mildew, rust, blight, &c., in wheat and other grains, the white rust in cabbages, the diseases of the vine and the potato, are all produced by fungi belonging to one or other of those two orders—chiefly the former.

Nor do the entophyta confine their assaults to the members of the vegetable kingdom. They attack living animals much in the same manner and with similar consequences. There are few animals, from man downwards, which they do not occasionally assail. In the mammalia, the skin, the roots of the hair, and the mucous membrane, are the chief situations in which these

parasitic plants are found. In birds, they infest the lungs and the eggs; in batrachians, the skin; in fishes the skin, gills, cellular tissues, and eggs; in insects the wing-cases, the articulations, and the intestines, as also their grubs and pupæ; in the myriapods the intestines; in the mollusca generally the eggs; and in slugs the vesicle. In the Natural History division of the English Encyclopædia, under the article 'Entophyta,' will be found a long list of those parasitic plants, and of the different parts of animals which they severally infest, with a description of some of the diseases which accompany or foster their growth. Among these, one of the most important, in an economical point of view, is the Muscardine, the disease which attacks the silk-worm, and which is always accompanied, if not caused, by the presence of a fungus named *Botrytis Bassiana*. The disease may also, it is said, be communicated to a healthy caterpillar by means of the spores of this plant, and it always proves fatal.

In the animal kingdom, as in the vegetable, the young are, in the earlier stages of their existence, parasitical upon their parents. In oviparous animals, this parasitic period terminates with the laying of the egg; in ovoviviparous animals with its discharge from the ovary; but in the case of the placental mammals, the parasitic life of the young continues during the whole period of gestation, there being always a direct communication between the circulatory apparatus of the mother and that of her progeny, which thus draws all its nourishment from her blood. The young mammal is therefore, during this period of its life, an entozoon parasitical upon its own species. In like manner the external bud of the polyp is an epizoon parasitical upon its own kind, until, by acquiring a mouth and tentacles, it can obtain food for itself. The young of the mammalia, especially the marsupials, may

also be regarded as epizoa or external parasites, so long as they are entirely nourished by their mother's milk.

In some cases, offspring are not only parasites but parricides. This occurs both among plants and animals. In the case of the desmids and diatoms, for example, the sporangium appropriates the entire substance of the conjugating parental frustules; while the young frustules, the progeny of the sporangium, in their turn, divide among them the whole substance of their parent, which thus dying itself revives in its offspring. The young brood of the foraminifera also divide among them the entire substance of their parent, and leave nothing but the empty shell. Each successive brood of the successive grub-nurse-forms among the cecidomyiæ actually devour their parent. The infant ophiurus, growing as a parasitic bud upon the parental pluteus, not only kills its mother, but steals her stomach. The eggs of the female *Ascaris nigrovenosa*, herself a parasite, having been hatched within her, the young brood, straightening themselves, begin spontaneous movements within the body of their parent. They then proceed to devour those of her eggs which may remain unhatched, and thereafter attack her own internal organs. They select the least vital portions first; but these having been eaten, they go on remorselessly devouring their mother's whole body, till they leave nothing but the skin, through which they ultimately eat their way, and issue forth a truly amiable brood.[1]

But it more generally happens that the young animals thus internally hatched, and proving so destructive to the organism whence they draw their nourishment, are the progeny of another creature, not the offspring of the victim on which they prey. The ichneumon-flies, for example, instead of allowing their progeny to devour

[1] *Quarterly Journal of Microscopical Science*, January 1866.

their own mother's vitals, introduce them, while yet in the egg, into other organisms on which they may indulge their voracity. Selecting a fine well-fed caterpillar, either of a moth or a butterfly, the female ichneumon-fly pounces upon it, and grasps it tightly by the back. Piercing its skin with a single stab of her ovipositor, a hollow tube with a very sharp point, she thrusts this instrument deeply into the body of the caterpillar, and an egg, at the same moment gliding down the tube, becomes embedded in the soft tissues of her victim. She now withdraws her ovipositor, and, advancing a little, she plunges it again into the writhing grub, and continues this operation till she has deposited from forty to fifty eggs in advantageous positions in its fat body. This done, she flies away, and soon perishes. The caterpillar is not prevented by this operation from passing by metamorphosis into the pupa stage. But the chrysalis having been formed, the eggs of the ichneumon-fly are hatched within it, producing little smooth white maggots, whose head, partially hooded, has a chewing apparatus well adapted to gnaw the caterpillar's tissues. These maggots commence their attacks on the fatty portions of their victim, avoiding at first the more vital organs. But they eventually devour the whole of its substance, and eat their way out of the pupa-case; so that, instead of the expected moth or butterfly, nothing emerges from the chrysalis but these maggots, which, being by this time well nourished and fully grown, straightway proceed to spin their own little cocoons, in which they pass the winter. In spring there emerge from these cocoons perfect ichneumon-flies, which follow the habits of their progenitors.

The Entozoa proper, however, which all belong to the Helminthozoa, present the most curious phenomena connected with parasitic life—embracing, as they do, meta-

morphoses, fertile nurse-forms, and concurrent modes of reproduction. These creatures are very widely distributed. Almost every animal, from man downwards, has its own peculiar internal parasites; nor is there any organ or tissue in which they may not be occasionally found. The brain, the eyes, the lungs, the liver, the bowels, the kidneys, the muscles, and the cellular tissues are all liable to be infested by them. The same entozoon may, in different stages of its existence, and under very diverse external forms, attack a succession of different animals—passing from one to another in the course of its metamorphoses, and haunting diverse organs and tissues in its successive victims—often inducing disease, not unfrequently death. Some of them, moreover, pass a considerable portion of their existence as free and independent animals, mostly inhabitants of the waters.

The class being so large and presenting so vast a variety, it is necessary to limit attention to those of them which are the most interesting, and whose history has been the most thoroughly investigated. These are the tape-worms and the fluke-worms. Both of those organisms are, in their perfect state, hermaphrodite, the former self-impregnating, the latter possibly, but not certainly, the same. They both undergo remarkable metamorphoses, and exhibit fertile nurse-forms, with diverse modes of reproduction.

The egg of a tape-worm, on being hatched in the interior of some animal by which it has been swallowed, generally gives birth to a minute larva, whose nearly homogeneous body is furnished with three pairs of very sharp spicules, by means of which it insinuates itself into the tissues of its victim, whence it probably finds its way into the circulatory system. It is thus transported to some organ or tissue suited to its further development. A fitting berth attained, it begins to undergo metamor-

phosis, and swells out into a vesicular organism, consisting at first of little else than a membrane filled with fluid, and having in different species diverse forms, generally either spherical or somewhat pear-shaped. This is the first nurse form. It ere long begins to put forth one or more buds analogous to those of a polyp. In the pear-shaped kinds there is usually but one bud, situated at the smaller extremity. In the more spherical sorts, the buds are numerous, and scattered here and there over the surface. In certain species the buds are formed on the inner surface of the enclosing membrane, and these, detaching themselves, swim about in the contained liquid. In some instances the gemmation takes place from both the inner and outer surfaces of the membrane, but all the buds growing on the outer surface remain attached. These buds vary in structure and appearance in different species. Some are sessile, others grow on short foot-stalks. They are generally provided with a circle of hooklets at the summit, and under these are suckers, also arranged in a circle. The hooklets are designed for attachment, the suckers both for attachment and the absorption of nourishment. In soft tissues, such as the substance of the brain, these organisms frequently attain a large size and prove fatal to their victim. Those haunting other tissues are smaller and less dangerous. If those creatures never enter any other organism than that in which they are developed thus far, they perish without ever attaining a higher development or the faculty of propagating their kind. But if the animal in which they have been bred be devoured by another, a fresh series of phenomena ensues.

On entering the stomach of their new victim the little buds become detached from the vesicle on whose outer surface, or in whose interior, they have been formed, and straightway begin a separate existence. Passing from the stomach into the intestine, they anchor themselves

by their hooklets to the lining membrane of the intestinal canal; and adhering also by their suckers, they by these means begin to imbibe the juices with which they are thus brought into contact. Secured in this position, they become the second and final nurse-forms of their species. By gemmation from their hinder extremity, they produce a new series of flat and nearly rectangular organisms, all linked together by means of two internal tubes, one on either side. They are united by a cross tube at the point where each of the organisms is linked to its neighbour. At first small in size and few in number, these organisms proceed to multiply rapidly, each addition being made from the posterior end of the nurse-form, which, however, does not itself increase in dimensions. Its progeny, on the other hand, grow quickly, enlarging as they recede from their source, but much more in length and breadth than in thickness.

It is to this chain of organisms that the name tape-worm is applied; but each link in the chain is itself a complete individual organism, although perhaps dependent to a certain extent on its connection with the nurse-form for nourishment. Nevertheless, it is most probably in great part nourished by absorbing, through its own skin, a portion of the fluids in which it is continually bathed. Each of these individuals, as it increases in size, acquires reproductive organs both male and female, and when fully developed becomes a perfect self-impregnating hermaphrodite. The eggs accumulate rapidly, one set of organs being employed to form their germs, and another set their yolk substance—each germ acquiring a portion of yolk during its passage towards a receptacle, in which it becomes impregnated. The hermaphrodite, having at length become almost entirely filled with impregnated eggs, breaks off from the chain and perishes, the eggs being set free by rupture of the skin. Having been thus

discharged from the body of the animal in which they have been formed, these eggs are scattered in all directions. Some of them adhere to blades of grass or to the leaves of other plants, and these find their way again into the interior of other animals along with their food. There they go through the same course as before, becoming developed into the primary nurse-forms first above described.

Before the relation between those nurse-forms and the tape-worms had been established, as it has now been both by observation and experiment, they were regarded as a distinct family of entozoa, and named Hydatids. One of them, for example, the *Cœnurus cerebralis*, infests the brain of the sheep, causing the fatal malady called the staggers. Its form is that of a nearly spherical vesicle, often attaining a diameter of two inches. It puts forth numerous buds scattered over its outer surface. These, growing on a short foot-stalk, have at their top a ring of hooklets, and round their thickest part a circle of suckers. When a dog or a wolf devours a sheep thus infested, and in eating the brain swallows one of those hydatids, the mass of the vesicle is digested in the stomach of the devourer; but one or more of the buds, escaping the action of the gastric juice and entering the intestine, fix themselves, and there each becomes the parent nurse-form of a tape-worm chain.

The Cysticerci, again, have more of the pear-shape, and produce at their small end a single bud, which is furnished with hooklets and suckers similar to those above described. They infest chiefly the internal tissues and organs, such as the caul and the liver, but sometimes also the muscles and even the eyes. One of them, the *Cysticercus pisiformis*, infests the caul of the rabbit. On the rabbit's being devoured by a dog, the whole of the cysticercus is dissolved in his stomach except the bud, which, passing into his intestines, there produces a tape-worm chain, known as the *Tænia serrata*. So also, the *Cysti-*

cercus fasciolaris, which infests the liver of the mouse, becomes, when received into the intestine of the cat, the fertile nurse-form of the *Tænia crassicollis*.

The *Echinococcus veterinorum* is another of these nurse-forms. It is a cyst whose walls consist of numerous concentric layers, and it contains a yellowish or reddish albuminous liquid. It is widely distributed, both as regards the various animals it attacks, and the organs which it haunts. It is remarkable for producing numerous buds, from both the outer and inner surfaces of the coats of the cyst, those produced in the interior detaching themselves and moving about actively in the enclosed liquid. These buds, on being received into the intestines of another animal preying on that in which they are bred, anchor themselves and become the fertile nurses of tape-worm chains.

More curious still is the history of the *Tetrarhynchus*, which, on reaching the tape-worm stage of its existence, inhabits the intestinal canal of the skate. The eggs, on being discharged by this fish, are swallowed by some other of much smaller size, and are hatched in its stomach. A second fish devours the first, and the newly-hatched organism continues its development in the devourer. In this manner it may pass through the stomachs of several fishes in succession, before it completes its first stage of development as a nurse-form. It is now vesicular in structure, and has four suckers with a sort of proboscis in the centre, by means of which it penetrates the walls of the intestine of the fish in which it has found a lodgment, and makes its way into the peritoneum. Here, having formed for itself a sheath, it produces within its vesicular body by internal gemmation an organism resembling a fluke-worm; and this last after a while produces also by internal gemmation the *Tetrarhynchus*, which detaches itself, and becomes capable of motion within the body of

its immediate parent. When the fish, in which this development takes place, becomes the prey of a skate or a shark, the integuments within which the *Tetrarhynchus* is developed are dissolved, and it escapes into the intestine of the devourer. Having there anchored itself, it becomes in its turn the nurse-form of a tape-worm chain, named by some authors the *Bothriocephalus*, by others the *Rhynchobothrius*. Each link of this chain becomes a perfect hermaphrodite, producing a multitude of impregnated eggs for the continuation of the species, which thus requires no less than three nurse-forms to bring it to perfection.

The life-history of the fluke-worm is not less interesting. This parasite has been ascertained to be derived by metamorphosis from a free swimming animalcule, which was long regarded as a totally distinct genus, and named the *Cercaria*. This creature inhabits stagnant pools. Its body is oval, and it has a long tail which acts as a propeller. Its head is somewhat triangular and sharp pointed. Under this form it penetrates the substance of some fresh-water mollusk, casts off its tail, and encysts itself. In this condition it remains for several months. During the interval the snail may happen to be eaten by a frog or a bird, in which case the further development will take place in the interior of the devourer. But even if the snail escape from thus becoming a prey to another creature, the *Cercaria* will nevertheless undergo its further development, and emerge from its encystment as a fluke-worm provided with both male and female generative apparatus. The organ which the fluke most frequently infests is the liver, and it then feeds on the bile; but it is also found in other organs and tissues.

It is the manner in which the *Cercaria* is derived from the eggs of the fluke that is most remarkable. These eggs

are generally found in still waters, where they adhere to the leaves of water-plants. They are thus taken into the system of fresh-water mollusks along with their food, and are hatched in their interior. From each egg there comes forth a minute ciliated larva, which after a while produces by internal gemmation an elongated organism, named a *sporocyst.* Minute at first, this organism grows rapidly, being well supplied with nourishing food, and having a well-developed digestive apparatus. When mature, it somewhat resembles the pupa of an insect. It has a roundish head, connected with the body by a collar. Its general form is nearly cylindrical; but towards the hinder part it has two lateral appendages, behind which the body tapers considerably. It has no generative organs adapted to the production of ova and spermatozoa; but the whole internal surface of its body appears to be capable of producing germs by gemmation. These buds becoming detached, drop into the general cavity of the body, where they are developed—some into sporocysts exactly resembling their parent, others into the more perfect form of *Cercaria.* On reaching maturity, this double progeny burst through the integuments of their parent, which is thus destroyed. Those of them which emerge as sporocysts follow the same course as their mother—producing by gemmation other sporocysts and *Cercaria.* But those of them which emerge as *Cercaria* escape into the water, and there commence an independent existence—swimming about actively by means of their long tails. Many of them perish without undergoing any further change; but those which find their way into another animal lose their tails, and after a prolonged period of encystment, much resembling the pupa stage of an insect, they rupture their cases and emerge as fluke-worms. These forthwith commence their parasitic mode of life, and acquire hermaphrodite reproductive organs by

means of which there are formed a fresh multitude of impregnated eggs, destined to go through the same course as before.

Another parasite which has recently excited much attention is the *Trichina spiralis*, which infests the flesh of the hog, the rabbit, and some other animals. When taken into the human stomach, it penetrates the intestine, lodges for a while in the peritoneum, and ultimately finds its way into the muscles. Its effects are dangerous, sometimes fatal. A representation of this parasite, magnified 400 diameters, is given in Plate P, fig. 2. The specimen was found in the flesh of a rabbit.

Such are a few of the curious phenomena of parasitic life. Strange and anomalous as, at first sight, the Entozoa may appear, as respects both their manner of existence and modes of reproduction, in neither do they depart from the general analogy of nature. Their manner of life differs not in any essential particular from that of the mammalian fœtus, during its sojourn in its mother's womb. Their metamorphosis, their fertile nurse-forms, their concurrent modes of reproduction, are all analogous to those found among insects, crustaceans, medusæ, and polyps. Indeed, it is only in their peculiar haunts that they differ from other animals; for while the latter soar through the air, tread on the ground, or glide through the waters, the Entozoa find an inner world of their own within the bodies of other creatures—feeding on their surplus food, imbibing their secretions, or devouring their tissues.

They are thus to be classed among the beasts of prey: nor are their habits more destructive than theirs; indeed, for the most part they are less. For all animals of prey utterly destroy and devour their victims; whereas it is only in a few instances that the attacks of the Entozoa prove fatal. Their existence is accordingly to be explained on the general principle of the widest possible diffusion of the happiness involved in life. These crea-

tures form a clear and extensive addition to the field of vital enjoyment. The sun-fish alone harbours no less than nine distinct species of parasites. Now, although they may often induce on other creatures discomfort, disease, or death, it cannot be doubted that the Entozoa themselves enjoy their abundant supplies of nourishment, and their generally warm, always secure, abodes. Nor does it appear improbable, that they may have even an exquisite pleasure in the final and fatal act, by which they perpetuate their kind.

The preference exhibited in nature for gradual over sudden transition, is well exemplified by the gradations between independent and parasitic life. We have first, family life—monogamous, polygamous, or polyandrious; second, gregarious life—herds, flocks, swarms; third, co-operative gregarious life, where animals unite for a common purpose, but without distribution of functions, as in the beavers and bower-birds; fourth, homogeneous social life, where animals of the same species associate together with distribution of function, as in the bees, wasps, termites, and most ants; fifth, heterogeneous social life, where animals of a different species are associated with distribution of function, as in the slave-making ants; and sixth, heterogeneous companionship, where animals of diverse species are found always or very frequently associated together, but without the one's being parasitic on the other.

In a paper by M. Van Beneden, read before the Belgian Academy, several interesting examples of this last sort of association are given—chiefly among marine animals. The whale carries about with it a numerous colony of barnacles. The *Holothuria* gives lodgment in its stomach to the *Donzella*, a small eel-like fish, as also to certain prawns and pea-crabs, which merely share the *Holothuria's* food. Ensconced under the star-fish, *Asteria discoides*, is found a small fish, *Oxibeles lombricoides*, while another small fish,

Stegophilus insidius, lodges in the mouth of *Platistoma*, a siluroid of Brazil, partaking of its food before it is swallowed; and similarly a crustacean, the *Cymothoa*, resides in the mouth of the black *Stromatée*, a fish of the Indian seas. A whole colony of little fish inhabit the interior of a sea-anemone, two feet in diameter, found by Dr. Collingwood in the China seas; and in a similar manner a medusa of our own coasts, *Chrysaora isoscela*, shelters under its umbrella a swarm of young scad.

Pea-crabs of different species take up their abode in the shells of muscles, clams, and other bivalve mollusks along with their proper inhabitants. Some little crabs hide themselves in the vent of a sea-urchin; while others, with a nobler ambition, ride on the carapace of the sea-turtle. Another, deficient in foresight, conceals itself in the branches of coral, until it is fairly built into the growing reef.

One of the soldier crabs, again, which inhabit deserted univalve shells, shares his dwelling with a nereid or sea-worm; while another takes as a fellow-lodger a small sea-anemone, which he feeds and tends—carrying it with him when he shifts his quarters. The crustaceous coat of some crabs—particularly the *Squinado*, affords a support for the growth of *Alcyonium*, *Sertularia*, and *Coryne*, which serve it for the purpose of concealment. Other crustaceans lodge in the interior of *Salpæ*, or of the *Beroë*, or the *Pyrosoma*.

One of the most remarkable cases is that of the *Remora*, which has the faculty of attaching itself temporarily to sharks and other fishes, by which it is carried about in its search for food. Of this faculty advantage is taken to employ it as a means of catching fish. Various other examples are given in M. Van Beneden's paper, of which an abstract will be found in 'Scientific Opinion,' Nos. 78, 79, 80.

CHAPTER XXII.

SPECIFIC VARIATION.

The term specific variation denotes that tendency, exhibited both by plants and animals, to depart to a certain extent from the primary type of their species, under the influence of extraneous circumstances, such as change of climate, soil, food, select breeding, or other modes of treatment. Such variations are always confined within moderate limits, and the varieties thus produced must continue to be subjected to the same peculiar influences, otherwise they will in a few generations relapse into the primary or wild type.

In the vegetable kingdom there may be recognised two sorts of varieties,—1st. Those which may be propagated by seed; 2nd. Those which can be perpetuated only by cuttings, slips, buds, or bulbs. The latter always revert to the primary type when they are sown. The first sort are termed races, and they originally spring from individuals that exhibit some slight departure from the parental type, arising either from some accidental circumstance, or some peculiar mode of treatment. The variation, slight at first, may, by its perpetuation in the offspring through select breeding, and by the continuation of the same circumstances or mode of treatment, or by increasing the intensity of those modifying causes, be augmented to a very considerable extent. In some cases, the variations have in the course of time become so great, that the original type can with difficulty be traced. Nevertheless

there are limits beyond which the variation appears incapable of being pushed. Among the most notable examples of these races are our common garden vegetables — cabbages, greens, kales, cauliflower, brocoli, Brussels sprouts, &c., all of which have been derived, by peculiar modes of cultivation, from the *Brassica oleracea*, or wild cabbage. Sea-kale, radishes, turnip, parsnip, carrot, &c., are all improved races from wild originals. Care in the selection of large and well-formed seeds for sowing, with ample supplies of appropriate manure, will do much to improve the race of certain plants, especially the different sorts of grain. Races are generally improved by being crossed one with another.

The perpetuation of particularly coloured or double flowers can be secured only by the second method. The different varieties of the rose, the tulip, the hyacinth, the dahlia, the aster, the hollyhock, and other garden flowers, as also the red varieties of the horse chestnut, can be perpetuated only by cuttings, buds, or bulbs. So also with the different varieties of fruit trees, many of which have been improved by diverse modes of treatment from wild stocks—as for example, the apple, the pear, the medlar, the quince, &c. If in any of these cases the seed of the variety be sown, the produce will revert to the original wild type.

In the animal kingdom, as in the vegetable, the proneness to variation is confined within definite limits. There are only a few genera in which the tendency exhibits itself to any great extent; and these are for the most part such as have been subjected to domestication. Even among these, moreover, variability is manifested in different degrees. Of all animals, the dog is that in which the greatest amount of variability has been observed. But the cat, an equally domesticated animal, shows it to a very much smaller extent. The amount of variation

which can be produced among horses, is also far less than what can be obtained among dogs, or even among cattle and sheep, whose variability occupies a position intermediate between that of the dog and the horse. Among birds, the most variable genera are the domestic fowl and the tame pigeon; yet other birds have been quite as much domesticated as either of these, without their exhibiting anything like the same amount of variability. Finches, turtle-doves, turkeys, geese, ducks, peacocks, show nothing like the same proneness to variation as do the barn-yard fowl and the rock-pigeon, which is the progenitor of all the tame varieties of that tribe. Evidently, therefore, the tendency to variation is a peculiar and inherited quality, very unequally distributed among animals, and most strongly developed among those which can be domesticated, and whose breeding can consequently be to some extent regulated by the interference of man.

Nor when varieties do manifest themselves in breeds more or less domesticated, is it always slowly and gradually. For example, among the domesticated peacocks, there has occasionally been produced, all of a sudden, a variety so marked as to have been mistaken for a distinct species. It has black shoulders, and differs from the common peacock also in the colour of the secondary wing-feathers, the scapulars, wing coverts and thighs. There are on record five instances of its sudden appearance within the last fifty years, and its offspring inherit its peculiarities. There has also sprung up, in a similarly sudden manner, a variety of the common pheasant, having a pale brown or dark cream-coloured tint, and displaying a less brilliant metallic lustre on the head and neck than the common pheasant. Nor is this sudden appearance of remarkable varieties confined to the animal kingdom. It is likewise observed among plants, especially

those of the kale and maize tribes. Among geraniums, and pansies also, the sudden appearance of striking varieties is known to all florists, and the same phenomenon is observed to a greater or smaller extent among other flowers.[1]

One of the most remarkable causes of specific variation in animals is any strong emotional impression, made on the pregnant parent in a variable species. Instances of the operation of this cause among human kind are so well known, that it is unnecessary to cite them. In the case of the lower animals, among the mammalia under domestication, examples are also not infrequent. The instance of Jacob's experiments with the flocks and herds of Laban will recur to the memory of every reader. But even among domesticated oviparous animals, emotional impression has been known to exert a powerful influence. A remarkable instance is given in the Proceedings of the Zoological Society for 1863, page 77. A bantam hen having, before laying her eggs, been frightened by an angry parrot, and thereafter set to hatch her progeny, one of the brood was found to have had its bill and feet so modified as to resemble those of a parrot. The specimen was sent to the British Museum.

Among wild animals displaying a certain amount of tendency to variation, its effects are generally counteracted by an instinctive counter tendency to cross-breeding. Hence, when an individual peculiarity more marked than usual occurs, it is rapidly obliterated; for the peculiar individual is guided by instinct to avoid mating with another having the same or a similar peculiarity, and to prefer for its mate an individual either of the normal type, or having a peculiarity opposite to its

[1] In the Zoological Gardens, Clifton, there is a Clematis which in 1868 produced large pure white flowers; in 1869 its flowers were all green; and in 1870 they came out variegated, white, green, and purplish pink.

own. Such striking peculiarities are merely extreme cases of that minute degree of variation exhibited among all gregarious animals—a wise provision, obviously meant to distinguish one individual from another. The shepherd knows every sheep in his flock; although to a stranger they appear all alike. From the operation of this tendency to cross-breeding, it happens that, in the natural state, and apart from the interference of man or of other intervening circumstances, the normal type of the species is preserved in spite of the proneness to individual variation.

It is only by select breeding that varieties are perpetuated or augmented; for the tendency to variation descends by inheritance, and is therefore liable to increase in the offspring under the influence of continuous close-breeding. This, however, does not take place, save under constraint of some kind—the natural instinct being quite the other way. The most usual constraining influence is isolation, brought about either by the interference of man or by other causes. Only a very small number of species will breed in confinement, or when subjected to any sort of restraint. But such as will breed in confinement can generally be made to vary from the normal type, where there is any proneness to variation in the species. By watching slight individual variations, and by mating such individuals as exhibit the same or a similar variation, man can always secure a perpetuation of the variety, or even augment its peculiarities. In this manner there may be produced varieties, departing from the normal type to such an extent as almost to appear like distinct species. Even in nature such a perpetuation may occasionally be caused by the isolation of aberrant pairs. For example, the tail-less cats, found in such distant places as the Isle of Man and the islands of Japan, have probably had their origin in the isolation of aberrant individuals,

whose peculiarity has been perpetuated by continuous separation from the normal type. In like manner, the dwarf variety of the horse, found in the Shetland Islands, is probably the result partly of the dwarfing influence of a cold climate with scanty food, and partly of the continuous close-breeding, induced by the isolation of the stock. But separation from the main body of the species is quite indispensable to the perpetuation of any variety; for if aberrant individuals be turned adrift, and allowed to breed freely with the rest of their species, the instinct of cross-breeding will in a few generations extinguish their individual peculiarities.

It is conceivable, indeed, that were a variation to an extreme extent by continuous close-breeding prolonged through many generations, the instinctive tendency to cross-breed with the primary stock, or with other very aberrant varieties from that stock, might be lost; but instances of this kind, if they ever occur at all, must be extremely rare. On the contrary, all varieties exhibit the instinctive tendency to cross-breed, and are generally invigorated by this process.

It is remarkable that the varieties produced by human interference are rarely, if ever, found among animals left in their natural state. The latter exhibit only a slight tendency to variation in one or more particular directions; and it is by taking advantage of such slight tendencies and judiciously matching them, that very aberrant varieties are ultimately obtained. There is no example, however, of the raising of an inferior species to one of a higher grade, by any system of select breeding. The variations produced by human interference are not seldom deformities rather than improvements, and some animals become deteriorated under domestication. For example, the tame peacock falls considerably short of the beauty presented by the wild specimens of that marvellously

beautiful bird. Neither can any of the curious varieties of the tame pigeon be truly deemed improvements on the wild rock-pigeon, however much they may tickle the fancy of amateurs. It is chiefly in those qualities that render them useful to man, that improvements can be said to be effected by cultivating certain varieties of any wild stock; but the normal type is generally a more perfect organism—more thoroughly balanced in all its parts and qualities, than are any of those abnormal varieties.

Select breeding is by far the most potent agent in modifying species. The effects of change of locality, climate, food, and other similar causes, are comparatively trifling. But slight changes, produced by such causes, if accompanied by isolation and consequent continuous close-breeding, may ultimately culminate in very considerable variations from the normal type; or in the case of a small species, they may even alter the normal type itself.

So far then as human experience goes, and apart from all speculative views as to what may have happened in bygone ages, and under circumstances no longer subsisting, the tendency to variation is limited to a few species, and even in these is confined within narrow bounds. In nature it is continually counteracted by the cross-breeding instinct, and it requires continuous close-breeding, rendered compulsory by isolation or other causes, to perpetuate any departure from the normal type of a species.

CHAPTER XXIII.

HYBRIDATION.

The production of hybrids, or cross-breeds between different species of animals or plants, some regard as unnatural. But this is an erroneous view; because, were any law of nature contravened in the process, hybridation would be impossible. On the contrary, it must be admitted that certain species have a natural tendency to intermixture with other species, although, in every case, a member of any of those species will breed with another member of its own, rather than with one of a different species.

In the vegetable kingdom, hybrids have been obtained among some of the higher algæ, by fertilising the germ-cells of one species with the spermatozoids of another. For example the germ-cells of *Fucus vesiculosus* have been impregnated by the spermatozoids of *Fucus serratus*, and produced a hybrid. But as a rule, the algæ do not seem prone to hybridation. Among ferns it is more frequent, and in collections of cultivated ferns, hybrids often make their appearance without recourse to any artificial means. These arise from the accidental transportation of the spermatozoids formed on the prothallium of one species to the prothallium of another species, where they unite with the germ-cell.

In flowering plants hybridation is still more frequent, and gardeners often avail themselves of the tendency to it wherever it exists. In this class of plants the process is easily accomplished by removing the anthers from the

flower whose ovule is to be impregnated, and shaking over it the pollen of the other species. It is remarkable, however, that if the foreign pollen and its own pollen be placed upon a stigma at the same time, the latter will be selected, and will penetrate into the ovule instead of the former, which will remain inert. Nay, even if the plant's own pollen be applied a little time after the strange pollen, it will supplant the latter, and will impregnate the germ-cell, as if it had been applied first and alone.

On the other hand, in the case of a hybrid flower, the pollen of one or other of the parental plants will be preferred to the hybrid's own, and will produce more fertile seeds. The progeny in this case returns more or less to the type of the parent whence the pollen comes. But what is more curious, a hybrid flower will sometimes produce more fertile seeds, when impregnated by the pure pollen of an allied species, different from that of either of its parents, than it will do when fertilised by its own. The greater number of hybrid plants are barren, and of those that are fertile the majority are much less productive of seeds than their parents. In a few instances, however, they are nearly as fertile as the parental plants, and in some cases their fertility increases in successive generations. But this increase of fertility is accompanied by a tendency to return to one or other of the parental types.

Sterility is more frequent in the pollen than in the ovules of hybrids, and always begins with a defect in the pollen. The ovules continue to be capable of fertilisation by a pure pollen, after that of the hybrid itself has become inert.

Hybrid plants, while they differ from both their parents, partake to a certain extent of the peculiarities of each. In some genera the hybrid more resembles the male parent, while in others it is more like the female. Among flowering trees it sometimes occurs, that the hybrid will produce not only flowers intermediate in

character between those of the two parental flowers, but also whole bunches of flowers which exhibit the pure characteristics, some of the flowers of the one parent, others of those of the other. The hybrid between *Cytisus laburnum* and *Cytisus purpureus* affords an example of this tendency; and here, even in the same bunch, there are found flowers differing one from another, as respects their degree of resemblance to those of one or other of the parent stocks. What is still more remarkable, the same phenomena are presented, even where the one of those trees is merely grafted or budded on the other.

In general, however, grafting or budding does not result in hybridation—both the stock and the graft retaining their own individual characteristics, without sharing those of the other. Nevertheless, exceptions to this generality occasionally present themselves, besides the example above mentioned. Sometimes the stock to a certain extent affects the graft; more rarely, the graft affects the stock. If the hornbeam (*Carpinus betulus*) be grafted on the common beech (*Fagus silvatica*), after a period of years shoots of the graft will appear, having leaves both of the hornbeam and beech. This is the more remarkable, seeing those two trees belong to different genera.[1] When the pear is grafted on the quince or medlar, the fruit becomes smaller and more highly coloured, and when it is grafted on the mountain ash, the fruit ripens earlier. The orange bears better fruit when grafted on the lemon instead of its own stock. So also apples and pears have their fruit improved by being grafted on already-established good varieties, rather than on the wild stock. The peach thrives better in this climate when grafted on the plum, than when allowed to grow from its own roots. In fruit-trees generally, seedlings, by being grafted on an old and good stock, may be made to bear fruit in a few years and of

[1] An example of this may be seen in the Zoological Gardens, Clifton.

good quality; whereas if left to grow from their own roots they might not bear fruit for twenty years or more, and then the quality would be bad. In all these cases, the stock exerts a certain influence on the graft, which may be regarded as an approach towards hybridation. On the other hand, when the yellow jasmin, with variegated leaves, is grafted on an allied stock, with healthy green leaves, the stock will also after a time produce variegated leaves. In this instance, it is the graft that affects the stock. In the case of the cytisus above mentioned, the influence is mutual.

The species which exhibit a capability of cross-breeding form but a small fraction of the total number of species of flowering plants. This number is supposed to be upwards of 200,000; but only from ten to twelve thousand have been made the subject of experiment. In not more than between two and three hundred of these has the attempt at hybridation proved successful. As a general rule, hermaphrodite flowers are proner to cross-breeding than those of diœcious plants. It is remarkable that, among the species between which hybrids cannot be obtained, are some which appear to be closely allied—as for example the apple and the pear, the currant and the gooseberry, the blackberry and the raspberry, and several others which seem to be as nearly akin.

While the tendency to cross-breeding between different species of plants may thus be regarded as comparatively rare, it is quite otherwise with varieties of the same species; for between these cross-breeds may be obtained with the greatest facility. Not only so, but the progeny of such cross-breeds generally exhibit, in some particulars at least, improvements upon their parents, and they are usually quite fertile. The proneness to cross-breeding in mere varieties affords a good general criterion by which to distinguish them from true species. This criterion is

particularly applicable to the case of closely allied species, such as those above enumerated, between which, notwithstanding their apparent relationship, hybridation cannot be effected.

Hybridation follows nearly the same laws in the animal as in the vegetable kingdom, with this exception, that it much more rarely occurs without human interference. It has been mentioned that, within the limits of a species, there is among animals a very strong instinct urging them to cross-breeding, and that by this instinct any tendency to indefinite variation from the normal type is neutralized. But beyond the limits of a species, the instinct is quite the other way. It is only under constraining influences that individuals of two different species will mate; and it is only in a few genera that such conjunctions are fruitful. It is possible that, were two individuals of different, but nearly allied species, through the operation of any natural causes, to become isolated each from its own species, they might, under the constraint of such isolation, have their natural instinct so modified as to pair; but instances of such a kind must in the ordinary course of things be of very rare occurrence indeed. Even in the case of fishes and other aquatic animals, where the germ and sperm elements are both cast into the water, there is always such a proximity as to ensure the conjunction of the germ with the sperm of its own kind; and natural hybrids among aquatic animals are thus extremely rare, if indeed they ever occur.

While the capability of hybridation is thus confined to a few genera of animals, there is a still further restriction upon the commixture of species, by the general infertility of hybrids between themselves. It is seldom indeed that hybrids prove to be otherwise than perfectly barren; but when they are fertile at all, it is for the most part with a pure individual of one of the parent stocks; and

the progeny will in that case to a certain extent revert to that pure stock. In this manner the effects of hybridation become obliterated in a few generations. Rare exceptions have arisen out of human interference; but in no instance has it been found possible to establish by hybridation a distinct species intermediate between other two. Even if hybrids do in a few cases prove fruitful between themselves, their fertility becomes exhausted in three or four generations.

It is thus evident that, while occasional hybridation is not contrary to nature, it is nevertheless not a law of nature that species should freely intermingle and produce fertile hybrids, so indefinitely modifying and confounding the characteristics of species. The cross-breeding instinct, so strong within the limits of a species, suddenly stops short and becomes reversed whenever those limits are overstepped. We never find wild mules, or hinnies, or a wild cross between the wolf and the fox, or between either of these and the dog; and although it has been found possible, by human interference, to obtain a cross between the hare and the rabbit, and such hybrids were said to be fertile between themselves, a cross of that kind has never been found in nature.[1] Indeed, although in the vegetable kingdom, natural hybrids may occasionally be produced by the intervention of insects, or by the operation of winds, yet in the animal kingdom there does not appear to be any well-authenticated instance of a hybrid's being produced in the natural state; nevertheless it is conceivable that such might arise from the accidental isolation of single pairs of allied species.

[1] Dr. Pigeaux has recently examined this case. While admitting the existence of the cross both ways, he denies the fertility of the hybrids between themselves. *An. and Mag. of Nat. Hist.* xx. 75.

CHAPTER XXIV.

LATENT LIFE.

So intimately associated in the human mind are the two ideas of activity and life, that it with difficulty regards as alive a being which has fallen into a state of inertness hardly distinguishable from death. There is here, however, as in many other natural phenomena, a gradation, by which the highest state of vital activity glides into death-like repose. There is first drowsiness, passing into dreamy slumber, then deep and dreamless sleep. There is the profound and prolonged sleep of hibernation both in plants and animals. There are the phenomena of fainting, catalepsy, coma, and suspended animation in asphyxia and drowning. There is the prolonged apparent inertness of the pupa in the case of insects, extending in some instances to twelve months; and there is, lastly, the more perfectly latent condition of life in eggs, seeds, and spores.

The faculty of pollen to retain its fertilizing power—the sole evidence of its vitality—for several years has already been noticed. Experiments are wanting to show whether the spermatozoids or spermatia of flowerless plants can preserve their latent life for similar long periods. The conidia of the fungi, the gonidia of the lichens, the zoospores and tetraspores of the algæ, all germinate very soon after separation from the parent plant. But the resting spores, as they are termed, of all the flowerless plants retain their latent life for very long periods of

time. Those of the confervoid algæ have been known to germinate after having remained for many years in a dry state in herbaria, and it seems to be favourable to their germination that they should first be dried.

Such spores are perpetually floating about in the lower regions of the atmosphere, driven hither and thither by the winds, and they do not germinate till they fall into a fitting soil, and meet with favourable conditions as respects moisture and warmth. It sometimes happens that, borne upon the breezes, multitudes of these spores fall in some particular locality, where they will germinate and develope themselves in a single night. This is more particularly the case with the confervoid algæ or silk-weeds—as for instance the *Palmella nivalis*, which tinges red the surface of snow, and *Palmella cruenta*, which suddenly appears on the ground in large patches, resembling clots of blood. The greenness, which sometimes appears quite suddenly in the waters of ponds and artificial lakes, is due to the rapid development of filamentous confervæ. These occasionally die as suddenly as they germinate. They then become whitish, and impart to the water a disagreeable smell and poisonous qualities, destroying the fish in the lakes. A case of this kind happened several years ago, during the months of April and May, in the artificial lake in the Zoological Gardens, Clifton. The water of the lake first became green, and soon thereafter of a milky whiteness and dreadfully fetid. The fishes rose to the surface, and after gasping a while died. This condition of the water continued for several weeks. It is not improbable that it was by some plant of this order that the waters of the Nile in 1673 were rendered of the colour of blood and fetid—continuing in that condition from July to December—and that they were brought into a similar state for a shorter period in the days of Moses. The probability of this phenomenon's

having been, on both occasions, produced by one of the confervoid algæ, suddenly developed from latent spores, is enhanced by the circumstance of the neighbouring waters of the Red Sea's having frequently a reddish tinge, which has been traced by Mr. H. J. Carter to the presence of a filamentous silk-weed, which has been named, after its first discoverer, *Trichodesmium Ehrenbergii.*

The blood-red stains which have from time to time made their appearance on bread, to the surprise and disgust of the beholders, and which also are occasionally seen in milk and on cheese, potatoes, cooked meat, &c., have been traced by Dr. Erdmann of Berlin to the presence of exceedingly minute organisms, which, while themselves transparent and colourless, have the power of producing, by their action on the organic materials which they infest, a bright red dye resembling that obtained from aniline.

It is probably to a similar rapid development of spores from their condition of latent life, that the sudden appearances of so-called manna covering the ground are to be attributed. The earliest recorded example is that of the manna which is mentioned as having been found every morning strowing the ground, while the Israelites were encamped in the Wilderness. The substance was probably named by them manna, from its resemblance to the manna of Sinai—an exudation from the tamarisk tree, which abounds in the Sinaitic peninsula. This latter substance, with which the Israelites were in all likelihood already acquainted, is a kind of mucilaginous sugar, and exudes from wounds produced by an insect of the Coccus tribe. Judging from modern instances, the substance which strowed the ground around the camp of Israel had only a moderate similarity to the manna of the tamarisk. The most, if not all, of the modern examples have been traced to the sudden development of the spores of the lichen named *Licanora esculenta.* In 1829, in Oroomiah, lying

to the south-west of the Caspian Sea, a famine having long prevailed, the surface of the ground over a large tract of country was found one morning, after a violent wind, covered with this lichen, which afforded a welcome supply of food to man and beast. In April 1846, in the district of Jenischehir, the ground was covered with the same substance to the depth of three or four inches. During the spring and summer of 1850, at Bayazid, near Mount Ararat, quantities of this lichen were found strowing the ground over several tracts varying from five to ten miles in circumference. It was always found lying in the morning, and never seen to fall from the atmosphere. The probability therefore is that the spores fell in the evening, and germinated during the night. This lichen has also been occasionally seen, under similar circumstances, in other districts of Western Asia and also in Northern Africa. It occurs in small irregular masses, from the size of a pin's head to that of a pea or small nut, and has no attachment of any kind. It has a sweet taste, and forms a good and nourishing food. This description answers so closely to that given in the Bible, as to leave little room for doubt of its having been the same substance on which the Israelites were, by a benign interposition of Divine Providence, nourished in the Wilderness.

As respects seeds, while in all of them the embryo retains its life in a latent state for a certain time, the length of the period varies greatly. The seeds of magnolia and coffee lose their powers of germination soon; whereas the grains of wheat retain it for a long time. The case of the alleged germination of wheat taken from Egyptian mummies would point to the duration of its latent life for many centuries; but those cases are now discredited.

A committee of the British Association was appointed in 1840 to examine this question and make experiments. This committee have made reports from time to time, and

from these it appears that the seeds of leguminous plants retain their vitality longest—there having been well-authenticated instances of their germinating after the lapse of fifty, sixty, or even 100 years. Seeds of hieraceum—one of the cichoracea—are stated to have germinated after having been for fifty years in a herbarium. A case in which raspberry seeds, found in a human body exhumed from an ancient tumulus in Dorsetshire, were alleged to have germinated when sown, was for a time doubted, but appears to have been subsequently confirmed. Seeds of scabiosa and heliotrope, found in ancient tombs, are also said to have germinated and grown up into perfect plants. It is remarkable, in relation to this question, that, when ancient forests are burnt or cut down, it invariably happens that there spring up in their stead a new set of plants, unknown to the place before. The majority of seeds, however, do not retain their vitality beyond eight years.

The instances above given show that vegetable life, as it exists in spores and seeds, may remain latent, without becoming altogether extinct, for very long periods of time. Experiments are wanting to determine how long life may be retained by buds and bulbs.

But even a fully-developed plant may have its life reduced, by protracted dryness, to the latent condition for a long while. This happens with nostoc, one of the confervoid algæ. When well developed, this plant appears in brownish, or dull green, folded or crumpled patches, about a fifth or a sixth of an inch in thickness, and sometimes two or three inches in diameter. Prolonged dryness will cause those patches to shrink till they are scarcely visible, so that they seem wholly to disappear. In this state, the vital activity of the plant is altogether suspended. But rain speedily swells the patches to their former dimensions, and the vital functions are

forthwith resumed. This circumstance produces the appearance of the plant's having grown all of a sudden.

In the animal kingdom, prolonged latent life is sometimes exhibited in the case of eggs, as, for example, in the winter eggs of the rotatoria, the daphnia, &c. Even a bird's egg, if it be gradually cooled after being laid, and if it be allowed to remain in a dry and cold atmosphere, may have its latent life preserved for a long time, and it will be restored to activity on being placed under a hen.

In the hibernation of bats, white bears, and other animals, we have an approach to the latent condition of life. But the most remarkable and perfect examples of latent life are those furnished by the rotifers, tardigrades and paste-eels. These creatures, on being dried, will remain in a state of latent life for years, and will immediately revive on being moistened with water. Alternations of the latent and active states have been produced by alternate wettings and dryings for as many as sixteen or seventeen times, but always with a diminution in the proportion of revivals. The paste-eel, *Tylenchus glutinis*, as also *Tylenchus tritici*, which causes the disease in wheat known as 'the purples,' are said to have been revived after having been kept dry for twenty-seven years—rotifers after a lapse of three years. These last have also been revived, after having been kept for a week under the exhausted receiver of an air-pump, in which dryness was secured by sulphuric acid, and thereafter heated in a stove to 267° F. In all these cases, the creature's active life is not prolonged beyond its natural term. On being revived, the animal continues to live the same number of days as it would have done, had its active life not been interrupted by the intervening period of repose.

Life, on passing into the latent condition, does not become wholly inert. It exerts a sort of conservative

influence over the chemical elements with which it is associated, retaining them in their subsisting combinations, and preventing the commencement of that decomposition, which would be the consequence of actual death.

CHAPTER XXV.

WHAT IS LIFE?

The foregoing chapters relative to vital phenomena have paved the way for a consideration of the question—What is life? Some physiologists have defined life to be 'a power to feed, grow, and multiply.' But this definition is only partially correct. It scarcely embraces the case of latent life, in which the only power exhibited is merely conservative—resulting in the retention of certain definite arrangements and relations of the material ultimates. Doubtless, there is in this case a latent faculty, which only awaits a favourable opportunity of manifesting the more active phenomena; but so long as the latent condition subsists, the definition is not strictly accurate. The imperfection of this mode of defining life, however, becomes more evident, when it is borne in mind that life must of necessity be an attribute of the Creator, of whom it is impossible to form any other conception than that He is a living Being, whose life is the ultimate source of life in all other beings. It is therefore needful to seek a definition that shall embrace life as it exists in the Creator as well as in the creature.

The following may be deemed sufficiently wide for this purpose. 'Life is an energy capable of influencing both the material ultimates and the physical forces.' It is not itself a physical force—understanding by that term a force exerted *by* matter, and not merely a force exerted *on* matter—but the physical forces, as well as the

material ultimates, are subject to its sway. Although this definition embraces life as it exists in the Creator as well as in the creature, and latent life as well as active life, there must nevertheless be a clear distinction drawn between creating life and created life; for it seems impossible to deny to the living energy of the Creator a power, not only to influence the material ultimates and the physical forces, but also to originate both the one and the other. Whatever view may be taken with respect to the past eternity of matter, it seems impossible to deny to the Omnipotent the power to have created matter, supposing it to have been at one time non-existent. This conclusion, however, does not prove matter to have actually had a beginning; for on this point, as already shown, there is not sufficient evidence to decide either one way or another. But even granting that matter may have existed always, it seems needful to suppose all the forces with which it is endowed—such as gravitation and the immensely greater force, which constitutes the elasticity of the luminiferous ether—to have been originated by the Creator; seeing these indicate the exercise of intelligent design, manifesting itself in determinate laws.

Since the Creator has power to communicate to other beings the life ever subsisting in Himself, it is reasonable to conclude that He possibly might, along with life, impart to a created being the faculty, which is inherent in His own life, of generating motion in the material ultimates. But that any created living being does actually possess such a faculty, we have no evidence. In so far as life and its phenomena fall under our actual observation, there is no proof of a living creature's actually generating physical force or motive energy. It merely exerts a certain influence on the motive energy or physical forces already existing, similar to what it exerts over the material ultimates themselves—and more

especially a faculty of converting one kind of physical force into another.

Confining our attention then to life as exhibited in known existing organisms, we shall most easily arrive at correct conclusions by contemplating side by side the two extremes—the highest and the lowest of animal organisms—man and the amœba.

To begin with man, our consciousness informs us that our life exists in a *somewhat* distinct from the material ultimates composing our organism. These ultimates are always changing—one set continually entering the system, and another continually departing from it; so that the human frame does not consist of the same individual ultimates for two consecutive moments of time. Even the entire organism undergoes great changes, particularly during the periods of growth and decay. Yet we never cease to be conscious of the persistence of our individuality; and memory helps to confirm this conviction. We thus arrive at the conclusion that the property of life, as it exists in man, is possessed by a somewhat altogether distinct from the matter composing his organism, and essentially different from it in nature. Physiology informs us that to this living somewhat are to be traced all the phenomena exhibited by the organism; for it is only during its presence that the phenomena are observed, or that the organism itself continues to subsist. The moment the living somewhat departs, the organism begins to be resolved into its constituent elements, in virtue of their chemical affinities. It is thus evident that the living somewhat is the organizer of the organism. By virtue of its inherent life, it so controls the material ultimates and forces, as to construct and uphold the organism, and cause it to perform all the functions for which it is adapted. This organizing faculty the organizer receives with its life from the living Creator.

Besides this faculty, man as a living creature is endowed with others which are more purely mental—such as thought, emotion, volition, memory, and the like. But there is no reason to suppose these to reside in an essence different from that which exercises the organizing power. We may therefore fairly conclude that it is one and the same being which thinks, wills, remembers, &c., and which, by feeding and breathing, builds and maintains the organism.

Descending to the lower animals, we observe in those most nearly resembling man in their organization phenomena so similar, that we must of necessity draw the same conclusion with respect to them—namely, that in every such organism there is an organizer in which the property of life resides, and by which the organism is formed and upheld—it being also to this same organizer that the faculties of volition, instinct, and memory belong. But the transition from the higher to the lower animals is so gradual, that what holds true of the one must be also true of the other; and we must conclude that there is a living organizer in the amœba, as well as in man.

The amœba offers this advantage, that we here observe the relations between the organizer and the organism reduced to their simplest conditions. There is no complex apparatus—not even any complexity of substance—nothing but pure sarcode without any fixity of form.[1] Yet there are in this simple being evidences of volition, as well as of the capacity to digest and assimilate food, and so to add by growth to its own substance.

The first lesson which we learn from this creature is that the organizer is co-extensive with the organism, the whole of which its presence pervades. This is proved by the power, which the creature exhibits, of putting forth

[1] There is an interesting paper on the amœba in the *Popular Science Review*, April 1866.

temporary legs and arms from all points of its surface indiscriminately, and in like manner of receiving food at all points of its surface, and forming an extempore stomach at any point in its interior. Moreover, if the amœba be divided into any number of parts, each part will exhibit the same phenomena as the whole, and will ultimately grow into a whole the same as that from which it was derived. Hence we learn that the organizer is equally divisible, as well as co-extensive with the organism.

While the organizer has thus the properties of extension and divisibility in common with matter, it may not be hence inferred that it is itself material. In other particulars it differs altogether from matter. All the material ultimates have the property of impenetrability. No two ultimates can exist in the same identical space at the same moment of time. Each ultimate excludes all others from the immediate site of its presence. But the living organizer co-exists in the same space with the material ultimates of which its organism is composed. These ultimates do not exclude the organizer from the immediate sites of their presence, neither does the organizer exclude the ultimates from the immediate site of its presence. They are not impenetrable the one to the other. In this fact we recognize an essential difference between the organizer and any material substance. The organizer, moreover, exhibits phenomena and modes of action altogether diverse from those presented by the material ultimates, when these are removed from under its influence. We thus learn that the substance of the organizer is quite distinct from matter, notwithstanding these two have in common the properties of extension and divisibility.

There is, however, a difference between these properties, as they exist in an organizer and in a material body. The latter is always definite in its extension, so that its

capability of division does not increase. All the parts into which a stone, for example, may be divided, must be smaller than the stone itself and must ever so remain. The practical divisibility of the stone is always approaching a limit, beyond which it cannot be carried. With an organizer it is quite otherwise. Each division is capable of acquiring, after a short lapse of time, an extension equal to that of the primary whence it was derived, or perhaps even greater, so that the capability of division thus becomes indefinitely augmented. If an amœba be cut into two, each half soon grows to be as large as the original whole, and may then in like manner be halved, and so on indefinitely, the organizer being multiplied as well as divided by this process. Thus, while it has two properties in common with matter—extension and divisibility—the organizer has other two wholly distinct from matter—penetrability and indefinite extensibility.

There is yet another property which the organizer has in common with matter, but under a modified condition. It is the capacity of forming combinations. In the case of matter, ultimate combines with ultimate, forming a compound molecule, with properties intermediate between those of the two combining elements. In like manner, an organizer can so combine with another organizer, as to produce a compound either intermediate between the two, or else combining the properties of both. But while the material ultimates merely unite and can be again separated, the organizers, in virtue of their penetrability and extensibility, become intimately blended throughout their whole extension; and the combination at the same time becomes both perpetual and indefinitely extensible.

The most simple illustration of this property is furnished by the conjugation of two diatoms. The frustules are undistinguishable the one from the other before conjunction, and each has an organizer coextensive with

itself, by which it has been formed. The two frustules conjugate and the two organizers blending unite to constitute a new organizer, with increased organizing power, by which a different and generally much larger frustule is formed. This larger frustule—the sporangium, spontaneously divides into numerous small frustules, each of which contains its own organizer; so that the organizer of the sporangium has thus multiplied itself by subdivision.

The recognition of these four properties in the organizer—indefinite extensibility, indefinite divisibility, penetrability and the capability of binary combination, helps to explain many phenomena of organic life. When an amœba is cut into two, its organizer is simultaneously divided into two, and each half becomes a separate individual, capable of exercising the same powers as the original whole, and of attaining the same or even a greater degree of extension. The like happens when the amœba separates into distinct portions by spontaneous fission. So also when a polyp is either cut into two portions or separates by spontaneous division, the organizer divides itself with the organism, and by virtue of its organizing faculty it repairs the lost parts. In the case of those organisms which multiply by spontaneous fission, the organizer must in like manner be held to divide itself into two new individuals, each endowed with the same organising powers, in virtue of which the parts wanting to form each half of the organism into a whole are completed.

Now fission has been shown to pass by gradation into gemmation; so that if in the case of fission we recognise a division of the organizer simultaneous with that of the organism, the same must be admitted in the case of gemmation. Each bud must contain an indefinitely extensible and divisible portion of the organizer capable of

becoming a separate individual, and of organizing a perfect organism, similar to that formed by the primary organizer from which it is an offshoot. This conclusion applies both to fixed and deciduous buds, whether they be formed by external or internal gemmation.

Again it has been shown that buds formed by internal gemmation pass by gradation into eggs; so that the germs of eggs must in like manner be regarded as each containing a subdivision of the organizer. In some cases this subdivision is by itself capable of organizing a complete organism like that formed by its primary, and in such instances it differs little from a bud; but more generally it cannot do so except in conjunction with another organizer. On the same principle, the pollen, spermatia, and spermatozoids of plants, and the spermatozoa of animals must all contain each a subdivision of the organizer. There is really no essential difference between these subdivisions, and those formed in the case of spontaneous fission and gemmation, except what arises out of the distinction between germ and sperm. In the case of subdivision by fission and gemmation, the severed portion has organizing powers similar and equal to those of its primary; and in virtue of these it can of itself fabricate a complete organism exactly resembling that which the primary had organized. But in the case of the differentiation into sperm and germ, the former at least can exercise its organizing faculty only after conjunction with the latter. Or rather it should be said, that the individual organizing powers of the sperm organizer extend no further than to the formation of the elementary sperm organism, be it pollen, spermatozoid or spermatozoon. till it blends with the germ organizer to constitute a new individual.

In this respect, the independent organizing powers of the sperm, fall short of those of the germ organizer; for

we have seen that, in the case of parthenogenesis the latter's independent organizing powers may extend beyond the formation of the mere germ element, even to the organization of a complete organism, quite as much as if the germ had been a bud, or a subdivision produced by simple fission. The powers of the sperm are more specialized than are those of the germ organizer; while the powers of the latter are more specialized than are those of the subdivisions arising from fission. For two of these subdivisions, undistinguishable from each other, may combine to constitute a compound organizer with enlarged organizing powers, as exemplified in the case of conjugating diatoms: but two germ organizers cannot so combine; they can unite only with sperm organizers dissimilar to themselves. On the other hand the new organizer, constituted by the conjunction of sperm with germ, has more enlarged organizing powers, than are ever exhibited by the compound organizer, constituted by the conjunction of two organizers, whose separate individuality has had its origin in simple fission.

That the result of the union of sperm with germ is a new organizer, combining the properties of both, is proved by many phenomena. Even in the human species it is found that offspring generally inherit certain qualities, mental as well as corporeal, from both parents. The combination of two distinct sets of organizing powers is rendered still more manifest in the case of hybrids, in which the resulting organism always exhibits characters intermediate between those of the dissimilar parents. A male organizer—that is an organizer which forms a male organism—is a combination of a sperm with a germ organizer, in which the organizing powers of the sperm predominate. A female organizer again—that which forms a female organism—is a combination of a sperm with a germ organizer, in which the organizing powers of the germ

predominate. That a female organizer possesses both sperm and germ organizing powers is proved by the Queen-bee's capability of producing male offspring by parthenogenesis; for in this case the sperm organizing powers must have descended to the offspring through their mother from her father, whose sperm organizing powers must have been latent in her. It is remarkable that when a Queen-bee is fertilized by a drone of a different, but allied species, her male offspring are unaffected by the cross. Only the females and neuters exhibit any of the characteristics of the strange father. The males inherit the pure characters of their grandfather, which had been latent in their mother. This latency of the sperm organizing powers, primarily derived from a male organizer, may even extend through several generations of females produced by parthenogenesis; but it always emerges at last by the females' producing only male offspring, in which the sperm organizing powers of their remote male ancestor acquire the predominance.

In these particular instances, it would appear that the female organizer has in her constitution a proportion of sperm organizing power greatly exceeding the portion of germ organizing power found in any male. But in the generality of cases, there is no evidence of this disproportion. The male seems to have as much of the germ element in his constitution, as the female has of the sperm element in hers. This is evidenced by the male offspring's generally inheriting as much from the mother, as the female offspring inherits from the father.

It is in virtue of the penetrability and indefinite extensibility possessed by each, that, when a sperm unites with a germ organizer, they mutually penetrate and form a new organizer, in which the extensibility and organizing powers of both are combined—perhaps even augmented. It is only in this manner that the qualities inherited by

offspring from the male parent can be explained. The quantity of matter which has been organized by the separate individual organizing powers of the sperm organizer, is so exceedingly minute, that it is impossible to suppose it to be what produces so great an effect on the offspring. The actual material ultimates, contributed by the male parent, must be eliminated from the system of the young organism at a very early period; yet the peculiar qualities inherited from the father remain, and in many cases do not become manifest until the offspring has reached maturity. By that time every ultimate of the organism has been changed. In what then, save in the organizer, can these peculiar qualities reside? If we recognise that the sperm elemental organism contains a subdivision of the male organizer possessing penetrability, indefinite extensibility and the power of binary combination with a germ organizer, the difficulty vanishes. For, on the completion of the union, a new individual organizer is constituted, having indefinite extensibility and the same organizing powers as were possessed by both the parents; and this new organizer, being composed of two subdivisions—the one of a male, the other of a female organizer, inherits certain qualities from either side; while in many cases it exhibits peculiar qualities of its own. In most instances, however, perhaps in every case, these last are inherited from some more remote ancestor, and are qualified by the peculiarities derived from the immediate parents.

Were material substance what is effective in determining the qualities inherited by the offspring, the portion contributed by the mother should in every case so greatly preponderate over what is contributed by the father, as to render his qualities scarcely appreciable in the offspring in comparison with hers. Moreover, were mere matter the sole means of transmitting the parental

qualities, how is it possible to suppose that identical ultimates could pass through several generations of females, and then re-appear in male offspring to such an extent as to determine their whole organization? But this difficulty and all others connected with inheritance from the male parent disappear, if we regard the means of transmission as being not mere material ultimates, but living subdivisions of the living organizer—the material ultimates serving as mere temporary vehicles for the conveyance of those subdivisions of the male, until they can unite with similar subdivisions of the female organizer.

Take for illustration the case of the aphis. Consider how minute a portion of actual material substance, contributed by the male parent, is contained in the impregnated egg of this insect. Now out of this egg there emerges a being, which has not the characteristic of either male or female, but which is capable of producing by internal gemmation on an average fifty subdivisions of itself, each of which eventually attains the same size as its immediate parent, and in like manner produces fifty subdivisions of itself. This procedure continues during the whole summer: and if not interrupted, it will result in the multiplication of the original aphis into several thousands of billions. Consider the enormous mass of matter which may thus become organized. Yet among all these aphides, there is not as yet a trace of the male element. The original aphis that came out of the egg, with all its offspring down to the ninth or tenth in descent, may have perished, yet of these descendents in the ninth or tenth degree, some will eventually ripen into perfect females, subdividing into germ, and others into perfect males subdividing into sperm elements. Can it be for a moment imagined, that these last result from the mere material ultimates which entered into the sperm element enclosed in the original egg? But if

we admit that, enclosed in the egg, there was an immaterial sperm organizer, having indefinite extensibility and divisibility, the whole system is at once explained. The aphis that came out of the egg, and every one of the thousands of billions that proceeded from it by gemmation, each contained an extensible subdivision of the primary sperm organizer, blended with a similar subdivision of the primary germ organizer; and the powers of these subdivisions, although remaining latent, perhaps only modified, for so long a time and through so many descents, yet ultimately manifest their presence by the organization of perfect male and female organisms, containing perfect male and female organizers, capable of subdivision into multitudes of sperm and germ organizers similar to those originally contained in the egg.

Even in the case of the human species, it is not uncommon to find offspring resembling some remote male ancestor, such as a great-great-grandfather, more closely than any of the intervening parents. Such resemblances sometimes extend not only to the external organization, but also to mental qualities. It is evident, then, that there is a *somewhat* which has been transmitted from the remote male ancestor, and which has thus affected the organization of the offspring; and seeing it is impossible to imagine that *somewhat* to be one or more material ultimates, the only supposition which can be reasonably entertained, is that of its being an indefinitely extensible and divisible offshoot from the immaterial organizer of the ancestral organism.

It is remarkable that sperm organizers, which are subdivisions of perfect male organizers, should be produced in such countless multitudes, as compared with germ organizers, which are subdivisions of perfect female organizers. This arises from the necessity of providing against loss. Not one among many thousands of sperm

organizers ever forms a junction with a germ organizer, so as to develop its latent powers. The immense majority perish in their elemental stage. But this is quite analogous to what occurs in many other cases, where provision against immense loss of life becomes needful. Of the numerous fertile seeds produced by plants only a very few ever germinate, and of these few multitudes perish in their earlier stages of growth. Of the spawn of fishes vast quantities are devoured before the eggs are hatched, and of the fry the immense majority fall a prey to their numerous enemies before they attain maturity. There is thus as it were an absolute prodigality of life in nature; and this simply because of the almost unlimited facilities for its reproduction. No provision has been made for reproducing the material ultimates, because not one of them is ever destroyed. Indeed, the quantity of organized or organizable material in the world being comparatively limited in amount, there is the strictest economy observed in its employment—the same materials being used over and over again. But in the case of living organizers, the facility of multiplication is nearly commensurate with the liability to destruction. We see that in the case of multiplication by fission, a living organizer loses nothing by being subdivided into two, or any greater number of parts; for the remnant retains its organizing powers unimpaired. And it is the same with the subdivisions ensuing from the production of the germ and sperm elements. The primary organizer suffers no loss by the subdivision—its organizing powers remaining intact. Nevertheless instances occur where the subdivision by fission, or by the formation of sperm and germ elements, proves fatal to the primary organizer. Of this fatality examples have already been given.

Another striking proof of the influences exerted by the immaterial organizer on the organization of the progeny,

is furnished by the effects of any strong external impression exciting emotionally the pregnant parent, of which instances have been already cited. These effects appear to be inexplicable on the supposition that nothing but mere matter and the play of purely physical forces are concerned in their production.

From the foregoing it follows that life is a property not of the material ultimates or of any assemblage of such, but of certain somewhats, which we have called organizers by reason of their having power to organize certain material ultimates into organisms. These organizers, moreover, cannot be themselves material, seeing they possess properties inconsistent with materiality—namely, penetrability and indefinite extensibility and divisibility. Besides these they have peculiar powers over not only the material ultimates, but also the physical forces, in virtue of which they can assemble and dismiss the ultimates, and compel them to perform motions altogether unlike those which they would perform if left under the influence of the physical forces alone. Not that the organizers, in so far as we have experience of them, actually generate motions in the ultimates, or originate any physical forces whatever. They merely avail themselves of existing forces, and direct them in a peculiar manner, so as to bring the ultimates under control and produce all the wonderful phenomena of organic life.

But the properties and powers of the living immaterial organizers do not stop here. It is they that are endowed with volition, emotion, instinct, imagination, memory, reason, consciousness—powers which it is idle to attribute to the material ultimates themselves. Seeing that we must recognise the existence of living immaterial somewhats, having volition, instinct, and the other properties above enumerated, it is reasonable to conclude that it is in these same immaterial somewhats, and not in any

others, that the powers of organization, by which organisms are formed, also reside, and that it is to their presence that all the phenomena of life are due. We have no grounds for supposing that there exist, in one and the same organism, two sorts of immaterial somewhats; one endowed with volition, instinct, reason, &c., and another endowed merely with organizing powers. The circumstance that volition is exercised consciously, and organizing power unconsciously, is not enough to warrant our regarding these two as being exerted by wholly distinct essences; the more especially as it has been shown that what exerts the organizing power must be quite as different from matter as that which exerts will and instinct. Some, moreover, of our mental powers are frequently exercised as unconsciously as digestion or the circulation of the blood.

Now, as regards the evidence in favour of the existence of the organizer, it is precisely of the same nature as what we have for the existence of the organism itself, or of any material object whatever. In both cases the evidence is purely phenomenal. All that is presented to the mind through the medium of its perceptions is a certain series of phenomena, and it is by an inference of the understanding deduced from these that the mind draws the conclusion that there do exist, exterior to itself, material objects and physical forces. But there is also presented to the mind, through the medium of its perceptions, a set of phenomena so diverse from the former, as to lead it to infer that, besides material objects and physical forces, there do exist other beings, differing from them in certain properties, though resembling them in others. Now in both cases, the deduction from the phenomena is reasonable—nor more so in the one instance than in the other; while, as respects the existence of the organizer, there is the additional evidence furnished by the internal consciousness of the mind itself, convincing it of its own existence. Not

that the mind apprehends by consciousness that it has any part in the unconscious organization of its own organism. This is also a deduction attained by reasoning from the phenomena presented to its perceptive faculties.

That in making these deductions in those several cases the mind acts reasonably, may be shown from its drawing an opposite deduction in the case of subjective phenomena. These latter often present themselves as vividly as any objective phenomena whatever; and it is only by an exercise of reason that the mind attains the conclusion that the subjective phenomena have no real basis external to itself, but are the results of peculiar conditions of its own sensorium. There are three principal kinds of these subjective phenomena, 1st. Those which occur in dreams, 2nd. Those which occur in nightmares, and 3rd. Those arising from illusions of the senses when we are quite awake. In the case of dreams we have, on awaking, little difficulty in convincing ourselves, by a slight exercise of reflection, that the phenomena were purely subjective, and that no real outward objects were presented to the senses. In nightmares, in some of which the phenomena are more vivid, and the deception of the senses more complete than in dreams, it requires a stronger effort of reason and a longer time before the mind becomes convinced of their true nature. All the five senses may be subjected to illusion in nightmare—sometimes in succession, sometimes more than one of them simultaneously. Nor is it easy for the mind to reason itself out of the belief that its senses have been impressed by some external agency, and attain the conviction that the phenomena have all had their origin in a peculiar affection of the sensorium arising from internal causes. In spectral illusions and other deceptions of the senses when we are quite awake, there is an equal, perhaps greater, difficulty experienced by the mind in convincing itself of the subjective character of

the phenomena. Still, in every well-regulated mind, the conviction is in all those three cases attained at last, and is then quite as thorough as the opposite conviction in the case of objective phenomena. Now there must be some foundation for this difference of conviction—some reason in nature—and we search in vain for any other than that which has been recognised by all sound thinkers, namely, that objective phenomena have a real basis external to the mind, while subjective phenomena are destitute of any such basis, and result merely from a peculiar affection of the sensorium.

The accuracy of this view is confirmed by those intermediate cases, in which objective phenomena are subjectively perceived, as when a single line is made to appear double by looking at it through Iceland spar, and generally in all cases where a false or peculiar perception is induced by instrumental or other means. In these cases, as in the former, reason must correct the perception in order to reach the truth.

If, then, objective phenomena are sufficient evidence of the existence of material objects and physical forces external to the mind, they ought to be equally admissible as evidence of the existence of a living organizer in every organism presenting the phenomena of life: for these, especially when contrasted with those exhibited by the same organism in death, are so peculiar as to render inevitable the inference, that there must exist associated with the organism a somewhat having properties other than physical, whose presence is indicated by the one set of phenomena, and whose departure is made manifest by the other.

CHAPTER XXVI.

PROTOPLASM.

In the 'Fortnightly Review' of February 1, 1869, appeared an essay on the physical basis of life, by Professor Huxley, in which he endeavours to obviate the necessity for assuming the existence of a living non-material organizer in any organism. He labours to prove life to be a mere property of matter, like gravitation or magnetism—manifested whenever the four elements carbon, oxygen, hydrogen, and nitrogen combine in such proportions as to form the substance which he calls protoplasm—a glairy material much akin to albumen, which he regards as the physical basis of life. Were it simply his meaning that, in so far as the basis of life is merely physical, protoplasm is most probably that basis, there would not be so much objection to his views; but he goes far beyond this point, striving to establish the non-existence of any other basis of life whatever, save this protoplasm.

Starting with that imperfect definition of life which makes it to be merely a power to feed, grow, move and multiply, he reduces even the higher faculties of man to mere molecular movements or changes, and thus embraces under his definition every faculty of every living organism, including those transitory changes classed under irritability and contractility.

His first illustration is drawn from the circulation of the sap in the sting of the nettle, and in the minute

hairs of other plants. This sap he holds to be protoplasm, and its movements to be due to irritability and contractility, similar to the like phenomena in animals. The vibratile cilia of the zoospores of the lower plants and their correspondence with those of ciliated animalcules, he adduces as proofs of the sameness of protoplasm and its movements in plants and animals—any difference which exists being one not of kind but of degree. In the lowest organisms the same protoplasm performs every vital function, feeding, growing, moving, multiplying, whereas in the higher, special portions of protoplasm are set apart for each function. He admits, however, the remarkable difference in function between the protoplasm of plants and that of animals, arising out of the power of the former to assimilate inorganic materials; whereas animal protoplasm can assimilate only matter already organized—the cause of this difference being unknown. So much for the similarity of function between the protoplasm of plants and that of animals.

Mr. Huxley next proceeds to trace their similarity as respects fundamental forms, taking for his first illustration the colourless corpuscles of blood, which are minute masses of protoplasm, and exhibit under the microscope movements similar to those of the amœba. In each living corpuscle he supposes to lie hidden a spherical nucleus, which comes more distinctly into view when under certain circumstances the corpuscle dies. Such corpuscles more or less modified exist in every portion of the human frame, and in its earliest stage the human foetus is nothing but an aggregation of them: so that every organ of the body was once no more than such an aggregation. The nucleated corpuscle of protoplasm is thus the structural unit. In its earliest stage the body is a mere multiplication of those units, and in its perfect state a multiplication of them variously modified. What

is thus true of the human organism is true also of every other animal frame from the highest to the lowest in the scale, until we come to a mere particle of living protoplasm, without any apparent nucleus, but capable of leading an independent life, and performing every vital function—animals of this simplest class forming a large proportion of the organic world. In like manner, all plants and parts of plants are mere aggregations of little masses of protoplasm, either with or without a nucleus, and either simple or more or less modified.

He then inquires what is the essential difference between animal and vegetable protoplasm, and proceeds to argue that, as concerns form, plants are not separable from animals, the distinction being in many cases conventional. Thus the *Æthallium septicum*, which in one of its forms is common on the surface of tan pits, is while in this condition a fungus; but De Bary has shown that in another condition, it is an actively locomotive creature, apparently feeding on solids; so exhibiting the most distinctive character of an animal. Founding on this very doubtful case, Mr. Huxley maintains, that there is no essential distinction between animal and vegetable protoplasm, which, whether simple or nucleated, is in every case the formal basis of life—all living powers being cognate, all living forms fundamentally alike.

There is here a forgetfulness of the functional distinction previously admitted to exist between plants and animals, as respects their powers of assimilation.

Mr. Huxley next proceeds to consider the chemical composition of protoplasm in both kingdoms. Making light of the objection that it is only dead protoplasm which can be chemically analysed, he points out that all its forms behave similarly towards several re-agents, and contain the four elements carbon, hydrogen, oxygen, and nitrogen, in complex union, forming the chemical

substance named protein. Albumen being nearly pure protein, he regards all living matter as more or less albuminoid. He will not affirm that all forms of protoplasm are alike affected by electric shocks, but he expects that they will ultimately be proved to be so affected. Nor will he assert that in all its forms it can be coagulated by a heat of 212° F. but he anticipates that ultimately it will be found to be thus universally coagulable.

While contending for this general uniformity of character in all protoplasm, he allows that there may be any amount of special modifications of this life-stuff—just as carbonate of lime presents itself under various modifications.

His next inquiry is into the ultimate fate and origin of this matter of life. On the first head, he shows that all protoplasm is doomed to die, and become resolved into its lifeless mineral constituents—that it is always dying, and could not live unless it died. He shows that every vital action involves a waste of protoplasm—that is, a resolution of this substance into dead elements or combinations of elements. Every word spoken resolves a certain amount of protoplasm into carbonic acid, water and urea. This waste is supplied by fresh protoplasm taken as food—whether animal or vegetable. In either case the protoplasm of the food is dead, but regains life on entering the living organism. In the case of animals, the food must be already formed protein, under one or other of its various modifications; but in the case of plants, the food may be purely mineral—water, carbonic acid and ammonia, which they have the power to convert to an indefinite extent into living protoplasm—the fungi however being an exception. But even plants cannot assimilate the chemical elements carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, &c., if administered to them in the pure state. The carbon must be supplied as carbonic

acid, and the nitrogen as ammonia. Thus the chemical ultimates of protoplasm are water, carbonic acid and ammonia, which have no properties beyond those of ordinary matter. From these the vegetable kingdom elaborates its own living protoplasm, which when dead maintains the life of the animal kingdom. Plants accumulate and combine these elements, animals disengage and disperse them. But on the pre-existence of these lifeless materials—carbonic acid, water and ammonia, the existence of protoplasm or life-stuff absolutely depends. He sees no reason why the four elements carbon, hydrogen, oxygen and nitrogen being called matter, and the various powers and activities of those substances being called properties of matter, protoplasm, which is compounded of them, should not be regarded simply as matter, and the various powers and activities of protoplasm, including life, should not be regarded as properties of matter. Taking for example water, he sees no reason why its various properties should be considered as due to a latent principle which might be called aquosity; and similarly he sees no reason why the various properties of living protoplasm should be regarded as due to a latent principle called vitality, or that life should be less regarded as one of its properties, than any of the other properties which it retains after having lost that single one. These properties, including life, he regards as solely the result of the nature and arrangement of its molecules, what are called vital actions being merely the play of the purely physical molecular forces of the protoplasm which exhibits them. Even human thought he holds to be nothing but the result, or manifestation, of chemical changes in our protoplasm.

Having thus stated his conclusions in terms as materialistic as it is possible to imagine, Mr. Huxley endeavours to repel from himself the charge of being a materialist.

Claiming to share to a certain extent the opinions of the Archbishop of York, in his essay 'On the Limits of Physical Inquiry,' and repudiating all connection with M. Comte and his Positive philosophy, he quotes from the Archbishop's work a passage giving an outline of the principles of that philosophy. But Mr. Huxley denies to M. Comte the credit of propounding these principles, assigning it to David Hume, and affirming that these very principles, although denounced by the Archbishop, afford the only way of escape out of the materialism in which his speculation on protoplasm had culminated. These principles are : 1st. That all knowledge is experience acquired by the senses. 2nd. The senses observe nothing of cause and effect, but merely one phenomenon following another. 3rd. The senses do not distinguish some qualities as essential, others as accidental, but merely that certain phenomena are presented by an object, some of which are invariable, others occasionally absent. 4th. All knowledge being relative, the notion of anything as being necessary is inadmissible.

And this is how Mr. Huxley endeavours to escape from materialism. He says that, were we to suppose that knowledge is not relative but absolute—that our conceptions of matter correspond to its reality—that we know more of cause and effect than a mere sequence of phenomena, and that we also know the necessity on which that sequence depends, from having a knowledge of necessary laws—on that supposition he sees no escape for himself out of materialism and necessarianism. For our knowledge of matter is as certain and definite as our knowledge of mind, and our acquaintance with law is as old as our acquaintance with spontaneity. He holds it to be impossible to prove any effect not to be due to a material and necessary cause, or to demonstrate any act to be spontaneous, seeing that, according to his view, a spon-

taneous act is one that has no cause. Hence the progress of science he holds ever to have been towards the extension of the province of matter and causation, and the banishment of such notions as those of spirit and spontaneity. He anticipates that the future progress of physiology will culminate in rendering the realm of matter and law coextensive with knowledge, feeling, and action (in other words, it will be proved that thought, knowledge, emotion, and action are all properties of matter and of the purely physical forces—there being no such things as soul, spirit, or mind. Yet this is not materialism. Oh no!), for matter and spirit are but names for the imaginary bases of different groups of phenomena.

Taking the case of the fall of a stone by the force of gravity, he says, we know that, if unsupported, the stone will fall by the action of that force; but we do not know that it must fall—that is, we do not know that gravitation is a necessary law of nature. Indeed, he repudiates altogether the notion of there being anything whatever necessary—the idea of necessity being baseless.

He then argues that if we have no knowledge of the nature either of matter or spirit, and there be no such thing as necessity, there can be no foundation for the dogma of there being in the world nothing but matter, force, and necessity; because such a dogma lies outside of the limits of philosophical inquiry. Mr. Huxley admits into his creed only these two articles: 1st. That the order of nature is ascertainable by our faculties to an extent practically unlimited; 2nd. That our volition has a certain influence on the course of events. Each of these articles he holds to be capable of experimental verification.

He next reduces the whole question to one of mere words, representing it to be indifferent whether we express the phenomena of matter in terms of spirit, or the phenomena of spirit in terms of matter, seeing matter may be

regarded as a form of thought, or thought as a property of matter. But in the interests of science he prefers the materialistic terminology; for by connecting thought with the other phenomena of the universe, it suggests inquiry into those physical conditions which accompany thought. Our knowledge of these, being more or less attainable, may help us to control the world of thought equally with the world of matter; whereas the spiritualistic terminology leads to nothing but obscurity and confusion of ideas. He accordingly anticipates that ultimately all phenomena will be represented by materialistic formulæ and symbols. He ends, however, with a warning against sliding from these formulæ and symbols into materialism, that is, from regarding them as representing realities. In other words, we may speak of matter and physical force, but must beware of imagining such things as either matter or physical force actually to exist in nature.

Such is the method by which Mr. Huxley fancies himself extricated out of the slough of materialism, into which his theory of protoplasm had plunged him. He first maintains life to be a mere property of protoplasm, then banishes from all regions of human thought such things as spirit or spontaneity; avows his expectation that the realm of matter and law will become coextensive with knowledge, feeling, and action, and then denies these opinions to be materialism, because the actual existence of such things as matter and physical force is a mere figment of the fancy. Mind, matter and force being thus banished from the world of reality into that of imagination—thrust beyond the limits of philosophical inquiry—there remain nothing whatever but phenomena. Each man is to himself and to all others nothing but a congeries of phenomena. There are no such things in the universe as beings or external objects, only phenomena,

and what takes cognisance of these is itself only a group of phenomena. This is the new philosophy of which Professor Huxley boasts himself a disciple. He is not a materialist, simply because he is a phenomenalist.

His manner of repelling the charge of materialism is much as if a man, who had wilfully poisoned another, should protest against his being called a murderer, on the ground of there being really no such thing as murder. He had merely altered chemically the condition of an aggregation of small masses of protoplasm; while he had after all done no real harm; because, having made his dogs devour the corpse, flesh, blood, and bones, he had put the whole of the dead protoplasm into a fair way of soon becoming once more living protoplasm, that is, of regaining one of its properties, which it had accidentally lost for a time. Or rather, to speak more in the phraseology of the new philosophy, the whole affair was nothing more than the phenomenon of one congeries of phenomena putting an end to another.

There is a strange inconsistency between Mr. Huxley's argument and his two articles of belief. For first he holds the order of nature—that is, all phenomena—to be to a practically unlimited extent ascertainable by our faculties; yet he maintains the non-existence of spirit or mind as the possessor of those faculties—what we call mind or spirit being merely an assemblage of a particular group of phenomena; consequently this group is capable of acquiring unlimited knowledge, not only of its own phenomena, but of all other phenomena whatever. Again, he holds the course of events to be affected by our volition, yet he banishes such an idea as that of spontaneity from all regions of human thought. Spontaneity being merely voluntariness or willingness, and volition a mere act of will, we have here will without willingness affecting the course of events, this will being merely one of a

group of phenomena, and at the same time one of the properties of that group. But will acting without willingness must act unwillingly, that is necessarily; yet there is no such thing as necessity, which Mr. Huxley affirms to be a mere empty shadow thrown by his own mind; that mind being itself nothing but a congeries of peculiar phenomena—of very peculiar phenomena indeed.

The truth is, that throughout the main part of his essay—that which relates to the basis of life—Mr. Huxley evades the real question at issue, namely, what is it that constitutes the difference between protoplasm while it is alive, and the same protoplasm when it is dead? To this question he gives no answer, and were he pressed to give one, his answer would probably be, 'I really do not know.' But if so, how can he know whether life (the name usually given to what constitutes the difference in question) be really nothing else than a property of protoplasm or not? Protoplasm being, according to Mr. Huxley, a mere congeries of phenomena—of impenetrability, indefinite divisibility, weight, bulk, semifluidity, temperature—all of which it continues to exhibit so long as it remains protoplasm, whether dead or alive; how should this congeries be capable of exhibiting for a time a totally different group of phenomena, embracing the assimilation of food, growth, movements opposed to gravitation, and self-multiplication, all of which are peculiar to living protoplasm, and disappear when it is dead?

Water, which possesses that assemblage of properties to which it pleases Mr. Huxley to assign the name of aquosity, but which most other Englishmen would call wateriness, never loses these properties, nor ever acquires any others, so long as it remains mere water. A drop of pure water can never assimilate fresh quantities of oxygen and hydrogen, or add to its own mass, or move contrary to gravity, or produce other drops of water like itself.

It never possesses, and can never acquire, what men call life. On the other hand, it can never, without ceasing to be water, lose the qualities of impenetrability, indefinite divisibility, weight, bulk, and so far as our experience goes, temperature, all of which properties it possesses in common with protoplasm. Neither can it cease to be composed of certain equivalent proportions of oxygen and hydrogen, or to behave in a definite manner in the presence of certain chemical re-agents. So also protoplasm cannot cease to be composed of certain equivalent proportions of water, carbonic acid and ammonia, or to behave in its own definite manner in the presence of certain chemical re-agents. Why then should it alone of all other substances temporarily acquire the property of manifesting the phenomena of assimilation, growth, motion opposed to gravity, and self-multiplication, and also lose this property without ceasing to be protoplasm? The two classes of phenomena being so entirely different, is it either reasonable or philosophical to conclude that the unknown bases of both classes must be one and the same?

But here also Mr. Huxley is far from being consistent with himself; for in his work on 'Classification,' published in 1869, at p. 10, under the head of 'Rhizopoda,' stands the following passage:—

'Nor is there any group of the animal kingdom which more admirably illustrates a very well-founded doctrine, and one which was often advocated by John Hunter, that life is the cause and not the consequence of organisation; for in these lowest forms of animal life there is absolutely nothing worthy of the name of organisation to be discovered by the microscopist, though assisted by the beautiful instruments that are now constructed. In the substance of many of these creatures, nothing is to be discerned but a mass of jelly, which might be represented

by a little particle of thin glue. Not that it corresponds with the latter in composition, but it has that texture and sort of aspect; it is structureless and organless, and without definitely formed parts. Nevertheless it possesses all the essential properties and characters of vitality; it is produced from a body like itself; it is capable of assimilating nourishment and of exerting movements. Nay more, it can produce a shell—a structure in many cases of extraordinary complexity and most singular beauty.

'That this particle of jelly is capable of guiding physical forces, in such a manner as to give rise to those exquisite and almost mathematically arranged structures —being itself structureless and without permanent distinction or separation of parts—is, to my mind, a fact of the profoundest significance.'

Yes truly, of very profound significance. And what is its signification? Simply that the mass of jelly—the protoplasm—is the consequence, not the cause of the life for whose phenomena it is a medium of manifestation; whereas the whole drift of the essay on protoplasm is an attempt to prove the contrary—namely, that life is merely the result of the combination in certain definite proportions of carbonic acid, ammonia and water, constituting protoplasm the physical basis of life, than which it has no other.

This theory of Mr. Huxley's has been ably and amply refuted, both by Mr. James Hutchison Stirling in his essay 'On Protoplasm,' and by Dr. Beale in his work 'On Life, Matter, and Mind.'

After some preliminary remarks on the systems of philosophy propounded by Kant, Hume, and Comte. Mr. Stirling begins his answer to Mr. Huxley with a sketch of the history of the cell-theory, in order to show that it culminated in the idea of protoplasm, as being the fluid

or semifluid contents of the animal or vegetable cell, divested of either nucleus or investing membrane. Under this name is thus embraced both animal sarcode and the primordial utricle of the vegetable cell. On the assumption that the basis of life is purely physical, Mr. Stirling denies, in common with the great body of German physiologists, that protoplasm, thus understood, can be that universal basis—contending for the cell, composed of membrane, protoplasm and nucleus, as being the living structural unit. He also denies that all organisms and all parts of organisms can have the same basis chemically considered—pointing out that the various tissues have not only the carbonic acid, ammonia and water, of which protoplasm is composed, united in different proportions and in diverse modes of arrangement, but that in some of them there is the addition of chlorine, sulphur, phosphorus, potassa, soda, lime, magnesia, iron, &c.; while even the elementary cells themselves differ chemically—some containing glycocine, some cholesterin, some protogen, others myosin. These are not mere modifications, but chemical differences, such as are commonly recognised as constituting diversity of substance. Mr. Stirling does not regard the objection that only dead protoplasm can be analysed, as being so frivolous as Mr. Huxley deems it; for several German physiologists have demonstrated a substantial difference between living and dead tissues.

As regards the behaviour of protoplasm in the presence of chemical re-agents, Mr. Stirling maintains that it is not identical in all kinds of protoplasm. That of the amœba has its motion arrested in iced water; while that of the trout's egg is quite lively in that chilly medium, but dies in a warm room. The protoplasm of the rotifers, the paste-eels and nostoc may be dried, yet live. That of eggs in general lives or dies according as it is exposed

to a heat differing little or much from what is congenial to the parents. That of some will die on the egg's being immersed in distilled water. If all protoplasm be alike, whence these differences in the effects produced on it by heat and other circumstances?

With respect to unity of form and faculty, Mr. Stirling quotes the German physiologist, Stricker, who maintains that protoplasm varies indefinitely in consistency, shape, structure and function. It is sometimes so liquid as to form in drops, sometimes it is semifluid, or gelatinous, sometimes stiff. The cells, in which it is contained, and which determine its shape, present an immense variety of forms. In its consistency it is mostly uniform, but occasionally interrupted. In function some is still, some in constant motion, while of some the function is unknown. The colourless blood-corpuscles, which are pure protoplasm, bear to the red corpuscles the proportion of only 1 to 450; yet Mr. Huxley would make the former to be the parents of the latter; in this disagreeing with some of the most eminent German physiologists, who maintain the reverse—alleging that sometimes fragments of the red corpuscles in the frog appear to be absorbed and assimilated by the colourless, and that the proper function of the latter has not been ascertained. Again, some sorts of protoplasm become converted into pepsin, some into fat, or perhaps pigment, or nerve tissue, or bone, or brain, or muscle, or various other tissues; yet these diverse sorts of protoplasm are not interchangeable; but each produces or becomes modified into its own special substance. There is, lastly, the indefinitely varied protoplasm of different plants and animals. Each of these has its own special sort of protoplasm, which is not interchangeable with any other, but becomes modified after its own peculiar fashion.

Starting with the eggs of animals, Mr. Stirling con-

tends that, not only is the protoplasm of the egg of each kind of animal different from that of any other, and not interchangeable with any other, but that even in the protoplasm of the same egg there are different portions from which are evolved diverse organs and tissues, and which are in like manner not interchangeable. He then combats Mr. Huxley's notion that the fundamental characteristic power in protoplasm is contractility; showing that there are various modifications of protoplasm, which are not contractile at all—as for instance the white of an egg, nerve and brain protoplasm; while, as regards difference of faculty, he contrasts the kidney with the brain; the former a mere strainer for draining off refuse, the latter the organ of thought, emotion, reason, and imagination. He reprobates Mr. Huxley's idea that the powers of man, as of the lower organisms, are to be summed up in these three—to feed, to grow, and to multiply.

Mr. Stirling next adverts to the extreme imperfection still subsisting in microscopical observations on organisms in their earliest stages, especially as regards the primary cell, its membrane and its nucleus—more particularly this last, of which the origin, the function, and the behaviour under various circumstances are far from being well ascertained. Hence he argues that the knowledge yet acquired by physiologists is insufficient to warrant the speaking of protoplasm as being in itself the one thing needful to life, far less the maintaining such an identity in all protoplasm as to justify its being regarded as the universal basis of life.

Passing from this topic Mr. Stirling proceeds to consider Mr. Huxley's second proposition—that all vital, emotional, and intellectual functions are merely the results of certain molecular dispositions and changes of the protoplasm. The argument on which this hypothesis

rests is the chemical analogy supplied by the formation of water when the electric spark unites its gaseous elements. Since under the stimulus of the spark, hydrogen and oxygen form an equivalent weight of water, and under the stimulus of pre-existing protoplasm, water, carbonic acid and ammonia unite to form fresh protoplasm, the resulting properties must be held to be purely physical, as much in the latter case as they are in the former. It is as absurd to attribute the properties acquired by protoplasm to a new latent entity called vitality, as it would be to attribute the properties of water to a new latent entity, which might be called aquosity. The vital properties of protoplasm stand on no higher level than the aqueous properties of water; all that is necessary in either case being to bring the chemical constituents together under certain conditions. The mode in which the pre-existing protoplasm operates to effect the combination in the one case, is not more unintelligible than is the mode in which the electric spark operates in the other. The conclusion drawn by Mr. Huxley is that all protoplasm being derived from pre-existing protoplasm must be reciprocally convertible, consequently identical, and the properties of life, emotion and intellect, must be quite as much the peculiar properties of protoplasm as aquosity is the property of water. Of this analogy Mr. Stirling points out the fallacy—showing that although water and protoplasm may be placed on the same level as respects mere chemical constitution, the latter has the additional quality of a capacity for organisation, of which water is destitute. The chemical analogy holds good only as between water and dead protoplasm; but there is no true analogy between water and living protoplasm. The analogy between dead and living protoplasm is confined to their chemical constitutions, if it extend so far. But that the life which constitutes the difference between

these two is merely an affair of chemistry, or of purely physical condition, cannot be proved by the analogy of water, which exhibits no phenomena at all analogous to organisation, emotion or intellect. Thus aquosity and vitality have nothing in common—no analogy that can justify an assimilation of the terms in which they are spoken of, or any reasoning from the one to the other. They are separated by the great gulf between life and death.

Mr. Stirling cites, in opposition to Mr. Huxley's views, the opinions of the most eminent German physiologists and philosophers, who maintain the difference between dead and living protoplasm to be constituted by the presence in the latter of a non-material somewhat, which is the antecedent of the organisation, quoting Kant's distinction, that, in a living body, the specific mode of existence of every part results from the whole; whereas, in a dead mass, the specific mode of existence of each part is independent of the whole. He argues that, as in the case of water, what constitutes the difference between that liquid and ice or steam is the motive energy of heat; so what constitutes the difference between living and dead protoplasm is the motive energy of life, the new phenomena in either case requiring a new explanation. There is, however, this distinction between the two cases, that, whereas the energy of heat operates from without, that of life operates from within.

He then adduces the evidences of design in the modes of operation of the energy of life, especially in the elaboration of organisms and their organs, demanding whether these can all be regarded as merely the results of certain molecular movements in the constituents of the protoplasm, arising solely from the circumstance of their consisting of carbonic acid, ammonia and water, combined in certain proportions and arranged in a definite manner. He next points out that, if such molecular movements be

of themselves unable to account for the phenomena of organisation, far less can they explain the phenomena of thought, of will, of emotion, of intellect—all of which must be traced to a non-material source.

The second branch of Mr. Huxley's analogy between water and protoplasm, that which relates to their modes of origin, is next examined ; and it is pointed out that our ignorance of the manner in which the electric spark acts, in combining oxygen with hydrogen to form water, and of the manner in which pre-existing protoplasm acts in producing fresh protoplasm, is no reason for our concluding the two modes of action to be at all analogous, but the reverse. For nothing can be more diverse in themselves than electricity and protoplasm ; and it is accordingly in the highest degree improbable that their modes of action should be similar. If pre-existing protoplasm be always necessary to the production of fresh protoplasm, whence the first protoplasm? (Nor is the action of the electrical discharge so mysterious as Mr. Huxley contends and Mr. Stirling allows. It most probably is purely mechanical. By forcing the ultimates of hydrogen and oxygen momentarily into greater mutual proximity than they can attain so long as they subsist in the gaseous condition, it brings them within that minute range of distance through which chemical attraction operates ; but protoplasm can exert no similar mechanical compulsion on the ultimates of carbonic acid, ammonia and water as could force them to combine into fresh protoplasm. This latter process is organic assimilation, and altogether unlike any other in nature.)

As respects Mr. Huxley's position that all protoplasm must be primarily identical, because vegetable is converted into animal protoplasm when taken as food, and *vice versâ*, Mr. Stirling shows this mutual convertibility to be only partial, poisonous protoplasm forming a glaring

exception. Neither can this convertibility transfer the functions of one sort of protoplasm to another. Human brains, supplied as food, would not enable any other animal, far less any vegetable, to think. (Would a fool become wise by feeding on the brains of a sage ?)

Glancing at Mr. Darwin's notion of organic derivation by the evolution of all organisms from a single primary, by means of the accumulation of small modifications prolonged through an indefinite period of time, Mr. Stirling inquires, how about the primary, the first cell, or the first lump of protoplasm ? Is it possible that any quantity of water, carbonic acid and ammonia could under the stimulus of sun, air or electricity, become protoplasm ? If not, then there must be some antecedent to the protoplasm—namely life ; and life being merely a property, it must have been possessed by some other antecedent which was not protoplasm. In reference to the effects of pre-existing conditions, Mr. Stirling asks whether odours produced the olfactory nerves ; whether light, acting on mere matter, produced eyes ; or sound, ears.

After combating a few other notions of Mr. Darwin and the molecularists, Mr. Stirling returns to Mr. Huxley with an explanation that, in arguing that life and thought, while they work through matter, are independent of it, he does not mean to affirm that they are unconnected the one with the other ; he merely maintains that life is neither a property nor a product of mere matter, but something higher than either matter or any purely physical force. There can be no such thing as a gradual transition from matter to thought, or from dead matter to that in which life is present, seeing life is in every case antecedent to organisation. After some remarks on the sense in which Mr. Huxley uses the term 'modification' to express all the varieties of protoplasm, and showing that the differences remain all the same in spite of this modified

phraseology, Mr. Stirling reaches the conclusion that Mr. Huxley's notions respecting the primary identity of all protoplasm, and the materiality of the basis of life, are alike untenable.

Dr. Beale begins his work on 'Life, Matter, and Mind,' by contesting the position that life is merely a variety of physical force, interchangeable with heat, electricity, &c., pointing out that the difference between life and death is not one of degree but absolute; for although living matter may suddenly become dead, the same matter can never, in the same form, resume the living state. If life be a mere physical force—a modification of heat or electricity (seeing no force is ever annihilated, but merely passes from one form to another), why cannot life, on leaving an organism, be traced into either heat or electricity, and so restored to its form of life; or why cannot the organism be prevented from dying by unlimited supplies of physical force in one or other of its forms?

Having challenged the supporters of the notion, that life is a mere physical force, to establish their position by facts, Dr. Beale first assails the views recently adopted by Professor Owen, that physical forces are being continually converted into vital forces, inanimate into animate matter, maintaining the older doctrine, that all living matter comes from pre-existing living matter. He shows the fallacy of Mr. Owen's analogy of the magnet, pointing out that, while a magnet can be unmagnetised and remagnetised at pleasure, an amœba cannot be thus killed and revived. Nor is the revivification of rotifers and paste-eels available to establish the analogy, for in those cases the animal is not killed, its vitality is only suspended, and when it really dies it cannot be restored to life. As regards ciliary motion, he denies its being truly vital, holding it to be a mere mechanical movement, due to the circulation of currents of fluid through the cilia.

Mr. Grove's affirmation, that in a voltaic battery and its effects, we have a near approach to experimental organisation, is next assailed, and the essential differences between a voltaic battery and an organism are set forth. No apparatus has yet been contrived capable of converting the physical forces heat, light, electricity, magnetism, or any others into life, so as to form a living organism from inanimate matter, without the aid of some previously existing living organism. Nor can any machine of human invention be made to assimilate food, grow and propagate its kind. Were life the result of the combined action of heat, light, electricity, or other physical forces, why should we not be able so to combine these as to produce life? but all these forces may exist in infinite quantity without resulting in life. The physico-chemical actions in a living organism are not to be confounded with vital actions—those to which the presence of life is indispensable.

From this topic Dr. Beale passes to protoplasm, and after showing the various meanings attached to this term by different authors, he takes up Mr. Huxley's notion of its being the physical basis of life, and exposes the confusion of ideas involved in his embracing under the same name matter about to become organized, matter already organized exhibiting vital functions, and matter which, having been organized, has ceased to exhibit vital functions. He also animadverts on the inconsistency between the views now advocated by Mr. Huxley, and those which he upheld not long ago.

He next shows the inaccuracy of Mr. Huxley's notions with respect to the layer of supposed protoplasm, which is found occupying the bottom of the sea at great depths, and to which that physiologist gives the name 'Bathybius,' imagining it to be primary protoplasm, ready to be formed, or to form itself, into all sorts of organisms. Dr.

Beale adduces the observations of Dr. Wallich to show that this substance is merely organic refuse diffused through the water, and constituting the food of some of the lowest classes of animal organisms, which assimilate it by absorption; but that, in itself, it presents no phenomena from which the pervading presence in it of life can be inferred. The errors of Mr. Huxley in supposing the analysis of dead protoplasm to be a sufficient indication of the constitution of living protoplasm; in his confounding the properties and mode of formation of such an inorganic substance as water, with those of organic matter which present the phenomena of life; and his thus trying to prove life to be a mere property of matter and nothing else, are then successively brought under review.

Dr. Beale next proceeds to an exposition of his own ideas. He holds all organisms to be composed partly of living matter and partly of formed matter, which has ceased to exhibit the phenomena of life, such as hairs, nails, the outer cuticle and parts of the dental tissue—the waste of these being either wholly or partially supplied by fresh living matter. Thus organic matter subsists in two conditions: 1st, living, active, formative; 2nd, lifeless, passive, formed—that which is in the latter having once existed in the former state. Only while in the first state does matter exhibit assimilation, growth, self-movement, and self-multiplication, or in general, formative power. Into this condition inorganic matter may pass suddenly under compulsion of the formative force, out of this condition organized matter may pass suddenly by being released from that force. He holds that matter cannot exist in a transitional state between these two conditions, although different portions of matter in these two conditions may be blended and connected together, the one exerting an active, the other a passive or resisting, influence on the other. Thus in reference to organization,

matter exists in three states: 1st, organizing matter; 2nd, organized matter; 3rd, food consisting either of organized or inorganic matter of determinate kinds. Only the first exhibits the phenomena of life. Dr. Beale calls it germinal or living matter; but this second term is objectionable, as involving the idea of its being the matter itself which is living, consequently that life is a temporary property of that matter. But the term germinal matter appears unobjectionable. Germinal matter is always either liquid or more or less glairy, but never either solid or gaseous; whereas organized matter and food may be in any of the three conditions, solid, liquid, or gaseous, and may assume any consistency or form whatever. Dr. Beale further limits the properties of germinal matter by assigning to it transparency, with absence of colour and structure, properties which it retains so long as it continues germinal, and does not pass into the second condition.

Drawing his first illustrations from the germinal matter of the sugar fungus and that of hair, he shows that in the former it assimilates food and grows at the extremity of each filament, which it forms as it advances; whereas in the latter it assimilates food and grows at the base of the filament, which it pushes on by forming new tissue behind. In either case the effect is due to an inherent power in germinal matter to move onwards in a determinate direction, sometimes opposed to gravity, without being urged by any external impulse. He considers germinal matter to exist in its simplest form in the amœba and the colourless corpuscles of blood, and believes that in all organisms and their organs it assimilates food, moves, and multiplies in the same manner; that while there are various sorts of germinal matter, differing in their relations to heat and food, their modes of motion, growth, fission, and conversion into tissue or

organized matter are uniform. Seeing organized matter often presents differences of structure and other properties, notwithstanding similarity or even identity of chemical constitution, such diversities can arise only from differences in the formative power in the germinal matter.

A chief characteristic of matter in this condition, Dr. Beale considers to be self-mobility in all directions, independent of external impulse; citing as an example the amœba, with its wonderful movements and changes of form, so different from aught exhibited by inorganic matter. He refers also to the phenomena of encystment and multiplication by fission exhibited by that creature. He next adduces the phenomena presented by the colourless corpuscles in mucus, pus, and blood; pointing out the resemblance of their movements and fissiparous reproduction to those of the amœba. (Klein has also observed the reproduction of these colourless corpuscles from others by fission, as in the amœba. Seeing they are thus so decidedly amœboid in all their characters, while their function seems to be quite unknown, ought not these colourless corpuscles to be regarded simply as parasitic amœbæ, inhabiting the blood and other animal fluids in which they occur, alike useless and, except when in excess, harmless to their host? Is not this view confirmed by the recently ascertained fact that, when portions detached from the colourless corpuscles find their way through the walls of the capillary vessels into the adjacent tissues, they undergo further development—becoming either pus-corpuscles or morbiferous germs, which are highly poisonous if they be again introduced into the blood, or even if they enter the system through the pores of the skin or the respiratory organs? May not the colourless corpuscle be thus regarded as a fertile nurse-form of the pus-corpuscle and the morbiferous germ, both of which are capable of very rapid multiplication by cell division?)

Dr. Beale shows that the moving force pervades the entire mass of the germinal liquid, and is not confined to molecules suspended in it, where such exist. These do not move in the liquid, but are moved by the liquid, so that the motion cannot be called molecular. Neither, he affirms, can these movements be due to differences of density in diverse parts of the liquid, or to diffusion arising from dissimilarity of composition in one part from another; for where there are differences of density, these are persistent and not arranged according to gravity, while the homogeneousness of the mass is evidence of there being no diversity of composition in the different parts. The movements, he maintains, cannot be ascribed to irritability without showing the source of irritation, nor can they depend on contractility, being distinct from those exhibited by tissues possessing that quality, such as those of the muscles, which are always performed in definite directions to and fro; whereas the motions of germinal matter take place in all directions indifferently. The movements of the amœba and colourless corpuscles he deems similar to those of the germinal matter in plants, as displayed in the leaf-cells of vallisneria, anacharis, and chara, or in the hairs of the flower of tradescantia. In some instances the movements of germinal matter in particular parts continue for many hours after removal from their proper organism. In other cases, especially among the higher organisms, they cease immediately on such removal. (Nevertheless young pigeons continue to fly about wildly and flutter their wings for several minutes after having been beheaded.)

The nucleus and nucleolus of the cell are next considered. These are always more intensely tinged by alkaline colours than the rest of the germinal matter, and are regarded by Dr. Beale as new centres of formative power. They may be few or many, and may appear in

successive series one within another. They never pass directly into organized matter, without first becoming germinal matter. When the nucleus attains this latter condition, the nucleolus becomes the nucleus, and within it a fresh nucleolus is developed. Quiescent germinal matter sometimes exhibits no nuclei at all; but these appear under the stimulus of increased nourishment. Although the nucleus becomes germinal matter, the latter is always the antecedent of the former.

From the nucleus Dr. Beale passes on to the mature cell with its enclosing membrane, holding it to be the structural unit in all organisms, excepting of course those consisting of pure germinal matter. Every cell which is either growing or capable of growth contains germinal matter either with or without a nucleus. When the cell no longer contains germinal matter, it ceases to be capable of growth and becomes organized matter. In that state it may be reabsorbed as food by fresh germinal matter, even in the same organism in which it was formed. The process by which germinal matter passes into organized matter, and ceases more or less to be associated with it, is illustrated by the instances of epithelial cells and cartilage, contractile tissue and nerve fibres, of all which representations are given. Every living cell consists both of germinal and organized matter, the latter containing the former, both being occasionally associated with matter about to become germinal by assimilation as food. Dr. Beale exposes the fallacy of the comparison of cells to the bricks in a wall, repudiating the notion of their being formed and accumulated by the mere play of mechanical and chemical forces, without the energy of the non-material vital power. The formation and nutrition of the cell is always due to pre-existing germinal matter, which operates by the assimilation of food. So also are all the changes which cells undergo, and their

multiplication in all its various modes. The alterations exhibited by cells in disease are traced to an undue and over-rapid increase of germinal matter, or to its deficiency arising from too scanty nourishment.

The question, What is life? next engages Dr. Beale's attention. He draws a distinction between the life of an entire organism, and that of the germinal matter which it contains. The organism may continue to live after much, but not all, of its germinal matter is dead. On the other hand, after the death of an organism, some of its germinal matter may continue to live. The phenomena presented by living bodies are distinguished into two distinct categories: 1st. Those which are purely chemical or physical; 2nd. Those of a totally different, and mostly higher order, which are never exhibited by purely inorganic matter. The difference presented by matter in these two states under the microscope is noticed. The inorganic matter and its molecular motions display appearances very diverse from those exhibited by the most minute and rudimentary organisms, whose movements are of a wholly different character, and whose increase in size and multiplication in numbers are phenomena never found in any purely inorganic particles. At this point he glances at the subject of spontaneous generation, expressing a strong opinion against the evidence on which the supporters of that theory rely, and maintaining that all organisms whatever spring from pre-existing organisms of their own kind.

A minute description is then given of the development of the spore of mildew under the microscope. The spore consists of germinal matter contained in an investing membrane of organized matter. If it be completely dried by heat, the membrane remains unchanged, while the germinal matter becoming solid undergoes decomposition, so that development is impossible. But if the spore be

kept moist and supplied with appropriate food, the germinal matter will attract that food to itself through the membrane, and appropriating it by assimilation will begin to grow. It is the germinal matter that forms the enclosing membrane, never the reverse. Yet gemmation proceeds from the outer surface of the membrane; but this is owing to the exudation of germinal matter through its pores. He shows that a cell or tissue of cells may be dead, though remaining part of a living organism; but the life which has departed from such cells, never passes directly into any other organism. For example, the life of a fungus, growing on dead organic tissue, does not take up the departed life from that tissue, but derives its life primarily from a pre-existing fungus of its own kind. (The same may be affirmed of all parasites, even those which attack germinal matter.) The impropriety of calling the merely mechanical or chemical processes occurring in organisms vital is pointed out, as also that of confounding such with the phenomena proper to life, and which are never presented except by germinal matter. He animadverts on Mr. Huxley's notion, that this germinal matter (protoplasm) has power of itself to guide and control the physical forces, as also on the opposite notion propounded by some, that the physical forces could of themselves guide and control the ultimates of matter—maintaining that it is life which guides and controls both the physical forces and the material ultimates; so moulding the latter into every variety of organic structure.

Dr. Beale next proceeds to distinguish vital from inorganic action. Growth he shows to be distinct from the mere accretion of the same elements, like what takes place when a crystal increases in size in a concentrated solution of its substance. In vital growth the process of assimilation frequently involves an alteration in the chemical constitution of the nutriment absorbed—not a

mere accrescence of surrounding materials similar in constitution to the absorbent germinal matter. No inorganic substance can assimilate to itself matter unlike itself as occurs in organic tissue; for example, when gelatinous tissue assimilates albuminous food. Moreover, organic bodies are continually parting with portions of matter which they have already assimilated, and assimilating fresh quantities of food, without necessarily increasing in mass—a process to which there is nothing analogous in inorganic bodies. Germinal matter is continually assimilating food unlike itself, and out of this elaborating materials also unlike either itself or the food. (Dr. Beale, however, in this part of his work expresses himself unguardedly in maintaining that the lowliest organisms require for their nutrition a certain portion of matter which has been already organized; for this is true only of animals and the fungi among vegetables, other vegetable germinal matter being capable of assimilating inorganic food. The protoplasm or germinal matter of the vegetable cell is continually assimilating simple carbonic acid, ammonia and water, combining these in certain proportions and in a definite arrangement, so as to constitute more germinal matter exactly like the first quantity, while it is at the same time forming out of its own substance every variety of vegetable tissue and material, all diverse in chemical constitution and structure from the primary germinal matter out of which it was evolved; but dead matter, such as a piece of wood, could not perform any similar feat.)

As regards the nutrition of animals, Dr. Beale considers that in the blood the colourless corpuscles alone are composed of germinal matter—the remaining constituents of that liquid consisting either of food about to be supplied to those corpuscles, or of organized matter which they have formed. He supposes that the chief use of the red

corpuscles is the distribution of heat, but that on their disintegration they partly supply food to germinal matter lodged in the various tissues, and partly pass off from the system in the form of urea, bile, and other excretions. The most nutritive part of the blood, however, he deems to be the serum, which, forming a coating on the surface of the red corpuscles, is by them distributed through the system. In the lower animal organisms which have no red corpuscles, the nutrient fluid resembles the serum of the blood of the higher animals, and is elaborated into their various tissues, including shell, cartilage, muscular and nervous tissues, &c. From the same food very diverse substances will be elaborated by the germinal matter of different animals and vegetables, and by different portions of germinal matter in the same organism. Dr. Beale ventures a speculation on the manner in which food passes towards the germinal matter enclosed in cell membrane—supposing it to be drawn in by centripetal currents, consequent on centrifugal movements in the molecules of the germinal matter. (But the analogy of dialysis seems to afford a better explanation. Albumen attracts to itself glycerine, colouring matter, &c., through paper or membrane, and Dr. Beale himself notes how germinal matter attracts to itself colouring matter through cellular tissue, so that there seems to be no reason for attributing to vitality this attraction and transference.)

Dr. Beale proceeds further to contest the position that life can be regarded as a property of matter, resting his argument chiefly on the power of self-movement, often in opposition to gravity, as belonging to an altogether different category from any property exhibited by matter, where life is not present; this self-movement being chiefly independent of structure or mechanism of any kind. He holds that all germinal matter is complex in its chemical constitution, and that its ultimates are

spherical; no simple substance being capable of constituting germinal matter by itself, or of manifesting any of the phenomena of life. He affirms that in the living cell there are perpetual movements of the molecules from and towards the centre of the germinal matter, the food going inwards and organized matter going outwards; and he hence infers that new centres of organisation are not formed by aggregation. Where such new centres (nuclei) are formed successively one within another, each new nucleus seems to acquire new properties in addition to those inherited from its predecessors; and these it transmits to its successor, which in like manner acquire additional and different properties, these being the result not of changes in the external conditions, but of the laws by which the whole process of organisation is governed. The formative force is most active when the germinal matter is apparently most quiescent; whereas an apparent increase in the activity of the germinal matter seems to result in a diminution of the formative force, and a tendency to decomposition of the already organized matter. He thus infers the presence of a power capable of controlling both matter and force. He thinks it necessary to assume the existence of internal forces acting from within, as well as of external forces acting from without, it being by the balance of these two that organisation is effected. But he holds the evidence of design, as exhibited in the elaboration of organisms, to indicate the presence of a non-material power of which, and not of the matter composing the organisms, life is the property. Nervous matter he regards as the most important of organic substances, at least in the animal kingdom, from its being the medium through which life influences other tissues, and also the medium for the action of will, instinct, emotion, and intellect, which are phenomena of life, but not vital power. The connection between matter and the

vital power for which it forms a vehicle of presence being temporary, he sees nothing contrary to reason in supposing that the latter may be freed from the former and yet be.

(This inference, as thus stated, is incapable of proof. Matter being infinite in its extension, and for aught we know also in its duration both past and future, the non-material can never be entirely freed from the material; it can exist nowhere apart from the material; nor can it be ascertained how far the existence of the one is, or is not, independent of that of the other. Nothing, or mere space, being incapable of proving the existence of anything else, the ubiquity of matter is our only proof of the ubiquity of spirit; nor can the presence of spirit be inferred, except from its influence on spirit, or on matter, or on some one or more of the physical forces. An intelligent observer at the European end of the Atlantic cable, on seeing the needle make a series of preconcerted signals, rightly infers the presence of an intelligent operator at the American end. But the matter of the cable, the physical force of electricity, and the influence of the intelligent spirit or mind of the operator are all equally needful to this inference. In this case we have the presence of spirit demonstrated by its influence on spirit, matter, and force. If the needle make wild and irregular movements, the observer infers the absence of an intelligent operator, and attributes the effects to earth-currents—to the matter and physical force alone, there being no evidence of the presence of an intelligent mind at the American extremity. Again if a boor see the movements of the needle, he, being unable to distinguish its regulated from its irregular movements, will wrongly attribute both to the influence of some imaginary mysterious spirit. And might it not happen that a philosopher, understanding all about electricity, but ignorant

of the preconcerted signals, and not distinguishing between the regulated and irregular movements of the needle, might attribute both to earth-currents, to the mere matter and physical force, ignoring the intelligent operator at the further extremity, to whose presence the regulated movements are due? In the two latter cases we have indeed spirit acting on matter and force; but from its failure to act also on other spirit, the truth is not attained.)

Dr. Beale next proceeds to consider the manner of action of nerve matter, maintaining its activity to be always traceable to the influence of germinal matter associated with it, either permeating the nerve fibres or enveloping them. An increase in the amount of this germinal matter augments, while a decrease lessens, the sensibility of the nerve. He attributes the nerve-current to changes in the germinal matter—chiefly in that accumulated in the nervous centres, but partly also in that associated with the nervous extremities. He identifies the nervous current with electricity, and demurs to its being regarded as any peculiar or unknown mode of force, or as a form of vital force. The mode of action of this electricity is determined by the structure of the nervous apparatus, which results from complex changes in the germinal matter out of which it has been elaborated by the vital power. But our ignorance of the exact constitution of this nervo-electric apparatus prevents our ascertaining how the electricity is brought into play by the germinal matter associated with the nerve structure.

From nervous action in general, Dr. Beale passes to a consideration of that special nervous energy which is manifested in mental phenomena. Its centre he considers to be the grey matter of the convolutions of the brain; while the nerve-cells consisting of germinal matter, enclosed in organized material, with the nerve fibres

intimately interlaced among the grey matter, he deems to be the instruments of its activity. The structure of this combination is so complex, and so inexplicable by the operation of any known physical laws, as to be referable to nothing but design. All mental activity he associates with changes occurring in a special kind of germinal matter present in the grey matter of the brain; such changes accompanying all mental excitement; while an undue increase in the quantity of this germinal matter is observed in delirium and over-excitement generally. He distinguishes mental nervous action from the reflex nervous excitement consequent on external sensuous impressions; maintaining that, while the latter are derived from without, the former emanate from within, and are to a great extent independent of outward impressions, as in all cases of meditation or abstract thought. Rejecting as absurd the notion that our ideas are secreted by the brain as by a gland, he also discards the hypothesis that thought is a mere function of the brain, as contractility is a function of the muscles, or sensation a function of the organs of sense. (He omits to notice that mental philosophers generally regard perception as being a function of the brain.) But will, choice, and abstract thought he refers to the mind's action on the brain as a mere instrument—the greater or less perfection of this instrument contributing to the result. While admitting that molecular movements, perhaps also chemical changes in the instrument, may accompany the mind's action, he maintains the latter to be the antecedent of the former and not the consequent.

Allowing that the brain may, in some sort, be compared to a collection of minute galvanic batteries and connecting wires, he points out that the mode in which these were formed, and so arranged as to produce their wonderful effects, cannot be explained by the operation of

mere physical forces acting without design. Neither can it be explained how these galvanic batteries should act of themselves without any external stimulus, as they do in abstract thought; so that the supposition of an internal stimulus becomes indispensable. Distinguishing thought from its expression, he shows that the latter is accomplished by a nervo-muscular apparatus, distinct from the instrument used in the formation of the ideas expressed, and that such expression always involves waste of material, whereas he holds abstract thought to involve no such waste. (This latter opinion, however, is hasty; for abstract thought, especially where it involves an effort of attention, reason, or memory, results in fatigue, consequent on the expenditure of physical force, and probably accompanied by molecular changes in the germinal matter of the brain. His notion also, that abstract meditation is not conducted in words, is contrary to the opinions of our best metaphysicians. Thoughts, not clothing themselves in words, would be vague and worthless, indefinite and nameless ideas. On the other hand, words often flit through the mind unaccompanied by the ideas they express.)

In further confirmation of his views, Dr. Beale mentions his having discovered, near the surface of the grey matter of the brain, and lying among the finest branches of the nervous fibres, numerous small masses of germinal matter, often extremely delicate and rapidly decomposable after death. He suggests that molecular movements or other changes in these masses directly affect the different nerve-fibres, and are the results of mental activity, which determines the direction of the movements and the particular nerve-fibres to be influenced. He supposes mind to be the vital power which thus acts; this delicate germinal matter being the special medium of its action, and distinct from that other germinal matter that excites the nervous apparatus through which ideas are expressed.

In constitution, however, there is no difference between this delicate germinal matter and any other, even that which is found in the lowest organisms, unless it be its extreme tenuity. Its peculiar properties Dr. Beale attributes solely to its more immediate association with the vital power. It exhibits one other physical characteristic, its rapid disintegration after death, which is probably due simply to its greater tenuity—the grosser kinds of germinal matter being more persistent, some sorts surviving for a considerable time the death of the individual organism in which they were formed, the germinal matter of pus and contagious germs being most particularly persistent, and most capable of resisting external influences. The delicate, perishable germinal matter, which is the medium of mental activity, dies under circumstances in which other kinds would grow and multiply. Nevertheless it often escapes harm in cases where the germinal matter concerned in expression may be seriously injured by inflammatory action, which affects the diverse sorts of germinal matter in the same organism successively and in different degrees; the lowest and least important sorts being the earliest and most powerfully assailed.

The germinal matter concerned in mental action is the last to be formed; although, like all other sorts in the body, it is evolved by descent from the primary germinal matter in the organism, and it continues to be formed even in old age. But, like other kinds, it may, in the course of its development, suffer arrest resulting in idiocy, or injury resulting in madness.

Will, Dr. Beale defines to be the power which influences the material particles, causing them to move and assume new positions. He deems it a power of the same order as vital power, and thus seems to restrict this last term to that which acts in all involuntary movements and changes. He identifies, however, will with mind, in its action on the

germinal matter, which is the medium of mental activity. (But this identification is rash; for abstract thoughts are often found in the mind, without the action of the will. For example, there will frequently arise in the mind involuntarily, without any external impression, the recollection of some injury, bringing with it re-kindled anger, or the remembrance of a bereavement, bringing with it re-awakened sorrow. So also in dreams, with much mental activity and many vivid ideas, the will is in total abeyance.) The germinal matter Dr. Beale holds to be the habitation of the metaphysical *ego*; and he winds up by admitting that, of the mode of action of this *ego*, or of the will, or of vital power on germinal matter, we know absolutely nothing — a conclusion in which all must concur.

From the foregoing analysis, it will be perceived that while Mr. Stirling and Dr. Beale both refute the hypothesis of Mr. Huxley, that the basis of life is purely physical, neither of them pushes the opposite argument to its just limits, by showing clearly what really is the basis of life. They call it a vital power, a something non-material, and even to a certain extent confound it with mind. They do not recognise it as in each case an individual being. They do not give it a distinctive name; nor do they define its properties, severing those peculiar to itself, from those possessed by it in common with matter. While, in a general way, they prove vital to be distinct from purely physical phenomena, they do not sufficiently particularize. They fail to point out that, as opposed to material impenetrability, the living organizer has perfect penetrability, in virtue of which it penetrates the entire organism. They do not show that it has indefinite extensibility, as opposed to material definiteness of mass. They recognise indeed its power of impulsion opposed to gravity, consequently its freedom from the physical law of gravitation.

They also discern its faculties of assimilation, growth and self-multiplication, of all which matter is destitute. But they do not show it to have, in common with matter, the property of indefinite divisibility, nor that of combination, similar to what is exhibited in the union of one chemical element with another; subdivisions of one living organizer being capable of uniting with subdivisions of another of its kind, so as to form a new individual organizer of the same species, in virtue of its penetrability and indefinite extensibility.

Again; while they admit design in the formation of organisms, and rightly refrain from attributing the elaboration of each individual organism to the immediate agency of the Creator (seeing the imperfections and occasional monstrosities in individual organisms exclude such a notion), they nevertheless fail to recognise the created organizer as being the agent which has, in every case, elaborated its own organism, acting in virtue of powers conferred by the Creator, and according to laws imposed by Him. They do not clearly show that the design manifested in organisms is not that of the created organizer, which operates unconsciously without intention, and is liable to have its modes of operation altered and modified by influences external to itself. Nor do they recognise the now subsisting organizers to be in every case, by direct descent, the offspring of those originally created.

So, also, they do not clearly distinguish a mind as being an organizer which, over and above its organizing powers exerted by it unconsciously, has been endowed with emotion, imagination, and intellect, which it exerts consciously, and which are properties foreign to matter, yet not possessed by every organizer. Dr. Beale, for example, speaks of the highest mental actions as being simply vital actions, occurring in living matter, instead of calling

them the actions of an intelligent living being exerted by means of germinal matter. Mr. Stirling again inclouds his notions on the subject in a fog of Teutonic phraseology altogether impenetrable. Both fail to discriminate that which has mere life and formative power from that which has, in addition to these, intellectual power, capable of exercising reason and judgment. Not that we have any grounds for supposing formative power and intellect, when present in the same organism, to be the properties of two distinct beings. For although there are organizers possessed of life and formative power, but without intellect, we have no proof of the existence of any beings possessed of intellect, but destitute of organizing powers.

As regards the hypothesis of Mr. Huxley that life, formative power and intellect are mere properties of matter, it is hoped that what has been urged, in opposition to his views, will satisfy most of those groups of phenomena, commonly called minds, that they are something more than mere aggregations of minute masses of that life-stuff, which he names Protoplasm.

CHAPTER XXVII.

THE GENERAL IDEA OF CREATION.

BEFORE proceeding further, it is needful to come to a distinct understanding in regard to the terms 'create' and 'creation,' as applied to organic beings. 'To create,' in the strict sense, is to cause that to be which had no previous existence, and this simply by an act of volition on the part of the Creator. In this sense, no organism can be said to be created. It is fabricated out of already existing materials; it is a combination of material ultimates and physical forces, both of which have previously existed in some other condition. But an organizer is not so constituted. All existing organizers indeed are subdivisions of previously existing organizers, or binary combinations of such subdivisions; but the first in each series must have been, in the strict sense of the term, a creation—a being brought into existence by the mere will of the Creator, and by Him endowed with life, and all those wondrous powers and properties which life involves. Among these the most essential is the power conferred on each organizer to organize its own organism. It is neither necessary nor reasonable to suppose the Creator himself to act directly in the organisation of any organism; it is enough to believe that He acts mediately, through the instrumentality of the organizer. We might as well suppose every instinctive action of an organized being to be a direct act of the Creator, as that every unconscious

action contributing to the development, growth, maintenance or reproduction of the organism is a direct act of Divine interference. In the one case, as in the other, it is the organizer that performs the action, in virtue of the powers primarily conferred by the Creator. Besides, as already noticed, the imperfections and occasional monstrosities occurring in individual organisms forbid our supposing these to be the immediate products of unerring creative wisdom and power.

When we speak then of the creation of an organic being, it is to be understood only of the organizer, not of the organism, which is, in every case, a form fabricated out of pre-existing materials. In strictness, creation can be affirmed only of the first organizer in any series. But inasmuch as every existing organizer is a mere continuation of some one first organizer or pair of organizers, notwithstanding its having by separation acquired a distinct individuality, it may still be regarded as having been created. It is an offshoot, however remote, from the ancestral organizer, and a partaker of the life and all the other properties with which that ancestor was endowed. That life and those properties have existed without interruption—passing through successive subdivisions of the primary organizer, each endowed with indefinite extensibility and divisibility. It does not follow from this view that the Creator may not have created many organizers with precisely the same endowments, in different parts of the world: for it was as easy for Him to create many as one. This is a question depending on evidence, and not to be determined by considerations of mere abstract probability.

The question of individuality is, at first sight, somewhat puzzling in this theory: but the difficulty vanishes when we view the gradations from separate individuality established by fission, to that arising out of ordinary

generation. When a diatom, or one of the fissiparous infusoria undergoes self-division, there can be no doubt that each half becomes a separate individual. Each is endowed with the same organizing power, consequently the organizer must have been divided into two individuals, each as extensible and as divisible as the primary. So, also, when a slip is taken from a tree and separately planted, it becomes a new individual, and may eventually attain the same size as the tree whence it was taken. In like manner, a bud cut from a polyp becomes a new individual, and each aphis that is produced by internal gemmation from a virgin aphis becomes a distinct individual from its parent. Nor is the case altered when the ova and spermatozoa of fishes are shed together into the water. Each spermatozoon and each germ of an ovum is a new individual in itself, and each is, moreover, by uniting with the other, capable of constituting a new individual exactly resembling one or other of the parents. There is no more an act of creation here than in the case of the diatom, the tree, the polyp, or the aphis. What we observe is the operation of a general law, to which organizers are subjected by their Creator; nor is there any greater necessity for assuming his direct interference as Creator in any of these cases, than in any of the other phenomena of nature. In all natural phenomena whatever there is a continuous action of the Deity, as superintending and directing the operation of his laws; but He neither ordains new natural laws, nor does He, so far as human experience goes, create new organizers. He has established it as a law that, when a sperm and germ organizer become, in virtue of their mutual penetrability, blended together, the result shall be a new individual resembling the originals of which it is an indefinitely extensible and divisible portion. Accordingly, when a species dies out, when the last organizer endowed with

the specific powers by which the organisms of that species were fabricated, has perished, it is never renewed by a fresh act of creation. The stream of life must be continuous; if once interrupted in any one of its numerous channels, it ceases to flow in that channel for ever.

As regards the individual organizer, although it may leave behind it parts of itself, which may each attain a new individuality, yet when any organism dies, its organizer individually ceases to exist. In the case of man alone are we permitted to believe that, when the organism perishes, its individual organizer, although ceasing to act, continues to be. But this belief, while reasonable, is not founded on mere reason. All analogy is against it. Indeed, it seems inexplicable how such an idea as that of the immortality of the soul could ever have entered the human mind, except as a conviction wrought in it by the spiritual influence of its Creator. Only on that conviction, strengthened by God's promise, and the testimony to the individual resurrection of his Christ, can we rest our hope that, when our present bodies shall have mouldered into dust, each individual organizer of our species shall be, after a time, re-endowed with formative power, in virtue of which it shall organize a nobler and everlasting human frame.

CHAPTER XXVIII.

ORGANIC GENERA AND SPECIES.

The ground has now been cleared for examining the important question of the origin of organic genera and species. On this point there may be entertained two leading views. The first is that the original organisms, from which those now living have descended, were formed instantaneously by a mere act of divine volition. The second is, that these original organisms were formed by a gradual process, and in accordance with determinate laws.

The first may be regarded as the popular view, and it has evidently been devised for the purpose of obviating, in a summary way, all the difficulties involved in the second. It is affirmed that it was as easy for the Creator to have formed a tree, or an elephant, in a moment of time, as by slow gradual growth; and as this idea saves the indolent mind from all trouble in forming conjectures as to the manner in which the first tree or elephant might have been formed by a gradual process, it hastily adopts it without further examination. But any reasonable mind, on endeavouring to realise to itself this conception of the instantaneous formation of perfect organisms, will soon begin to have misgivings as to its probability. The notion, that the butterfly, the frog, the eagle, the dog, the horse, the lion, the elephant, the gorilla, and man himself, all leapt instantaneously out of

the ground perfectly formed, will begin to appear so incongruous—so unlike what we know of the divine methods of procedure generally, that some hesitation will be felt about acquiescing in it without further inquiry. The mind will ask itself on what its belief in such an idea rests. It will soon discover that there is not a single fact on which it can be based; for it cannot be affirmed that, in so far as human experience extends, there ever has been such a thing as a perfect organism leaping suddenly out of the ground, or being instantaneously formed in the waters.

Adopting the more reasonable view, then, that the earliest organisms were formed by a gradual process, according to certain determinate laws, two hypotheses may be framed in regard to that process and those laws. The first is that all existing genera and species have been derived from previously existing organisms simpler than themselves, these being in like manner derived from others more simple, and so on till we arrive at a few exceedingly simple forms which were the progenitors of all the rest, or perhaps even to one such simple form, which was the progenitor of all other organisms. The second hypothesis is, that existing organic genera and species have all been derived from progenitors similar to themselves, and that the original organisms, so far from being fewer and simpler, were greatly more numerous and varied than the now existing genera and species, many having perished through the failure or destruction of their descendants. That these original organisms formed one vast system perfect in all its parts, the members of which were variously linked together by interlacing bonds of connection—one form passing into another by almost insensible gradations. But owing to the loss of a vast number of its members, the series now presents a fragmentary aspect, many of the connecting links being

absent. No small number, however, of these missing links are found embedded in the strata; and could the whole of these be restored, we should then be able to view the organic system in its integrity. Its unity of design, however, is to be regarded simply as an evidence of its having emanated from a single Creating Mind, and not as an indication that all the forms have been actually derived by modification from a single primary, or from a few such.

Applying the phraseology suggested in the preceding chapter, we should say that, according to the first hypothesis, the Deity created only one organizer, or at most only a very few organizers, endowing them not only with organizing faculties, but with a power to vary these in their extent and modes of action almost infinitely. According to the second view, the Deity, during the creative epochs, created in succession an immense number of organizers, endowing each with specific and limited organizing faculties—these, however, being liable to slight modifications in their action through the operation of extraneous causes. By these originally created organizers, all organisms now existing, or that have ever existed, were organized according to determinate laws, in virtue of the specific powers conferred on them by their Creator. For the originally created organizers, being each indefinitely extensible and divisible, all existing organizers are mere derivations from them; the life originally imparted to them having descended in a continuous and uninterrupted stream to those derivatives, together with all the other powers with which the primaries were endowed.

For brevity's sake, the first of these two hypotheses may be termed the theory of organic derivation—the second the theory of specific creation. It will be necessary to devote some space to the consideration of each.

CHAPTER XXIX.

ORGANIC DERIVATION.

The theory of organic derivation is that which has been so ably developed by Mr. Darwin in his 'Origin of Species,' a work which those who wish to see all that can be urged in favour of the theory, or in answer to objections to it, will do well to study. Nothing beyond a meagre sketch can be attempted here.

The foundations on which the theory rests, are the observed phenomena of specific variation, and the bonds of connection by which all organic forms are more or less linked together. These last are interpreted as indicating a community of origin; while the variations are regarded as evidences of the possibility of great departures from any normal type, and of their becoming permanent.

Several species exhibit the tendency to variation in a remarkable degree, as for instance the dog and the tame pigeon; but as there is some uncertainty about the origin of the varieties of the dog, while those of the tame pigeon are known to have been all derived from the wild rock-pigeon, these last are regarded as the best examples of the plasticity of a species. The variations from the normal type, which ever and anon occur among wild pigeons, are always slight; but by selecting such slightly aberrant forms, and breeding from them exclusively, pigeon fanciers are able to augment the divergence to such a degree as to established a well marked variety, so

distinct from the normal type that, were it found in nature, it would be deemed a distinct species. Now what is thus effected by artificial selection may, it is argued, be also accomplished by natural selection, operating in a similar manner under peculiar circumstances, through long periods of time. Suppose, for example, that the same pair of wild pigeons, which were originally selected as the foundation of any of our peculiar breeds—say the fan-tails—instead of being separated from the rest by man and made to breed in captivity, had by a gale of wind, been driven to some small island where there were no other pigeons, it is in the highest degree probable, that a breed of fan-tails, resembling those in the dove-cot, would, in the course of several generations, have been established in that island.

But this sort of natural selection might be fostered otherwise than by accidental isolation. All animals tend to multiply very rapidly; and if not checked by various causes, their multiplication would become excessive. One of those checks is the preying of one species upon another, and a second is the limitation in the supply of appropriate food. The former cause establishes a perpetual struggle for existence between different species—the latter a similar struggle between individuals of the same species. It hence arises that, whenever in any species a slight modification in the normal type of structure occurs, if that variation be at all profitable in enabling the individual either to escape from its enemies, or to obtain food more easily than its fellows, it has a great chance of being perpetuated. For the individual possessing those advantages will be kept in better condition than the rest, and will produce more numerous and healthy offspring, all of which will inherit the parental peculiarity. If again this improved offspring breed together, the peculiarity will be augmented in the

next generation, and provided there be no cross with the primary stock, it will go on increasing from generation to generation, until the peculiarity become so marked as to establish a distinct variety or even species. This cause, operating through countless ages and in various directions, would tend to render every slight modification of structure, which might be of any advantage in the universal struggle for life, permanent, and that in an exaggerated degree.

If, for example, a long bill were of advantage to any bird in obtaining food, or in fighting for it with its fellows in a time of scarcity, were an individual to be hatched with a bill longer and stronger than usual, it would in the struggle for life have a decided advantage. On supplies becoming scanty, it would keep itself in good condition by driving off its neighbours from the food, and would thus continue strong and healthy, while the others became weakly or perished. The offspring of this strong bird would accordingly be both more numerous and healthy than those of the other birds, and they would all inherit the parental bill. If these mated together, the second generation would have still longer and stronger bills; so that ultimately, after a vast number of generations a very long billed bird might be produced, although the remote ancestor had one of only a moderate size.

But were this the universal mode in which variations become augmented and perpetuated, the result would be the continual improvement of every species; so that all weak and defenceless organisms would ultimately perish, and none but strong species, able to maintain themselves amid the general struggle for life, would survive. There are, however, other causes, which might operate in an opposite direction. A few pairs of a species might, by a combination of circumstances, be brought into such a

situation, as to render some member or organ wholly useless in maintaining the struggle for life. In this case, the member or organ would cease to be used, and by disuse would be weakened. Their progeny would all be born with this member or organ in a like weakly condition; and as it would never be used by them, the weakness arising from disuse would continually increase, so that the next generation would be born with the member or organ still further diminished in strength, perhaps also in size. From these causes, operating through a very long succession of generations, a member or organ might become exceedingly reduced, or even altogether obliterated, and the whole organism might thus become so much altered, that the variation from the primary type would be extreme, and the remote descendants from the original pairs, placed in those peculiar circumstances, would come to be regarded as of a different species from the descendants of other pairs which have preserved the primary type. In this case the result would be a degradation instead of an improvement in the form.

Thus suppose an insect to have considerable powers of flight, and to exercise these in obtaining food. Imagine a few pairs of this species to be by some cause transferred to another region, where they could obtain abundant food without flight, and where, on attempting to fly, they found themselves assailed by deadly enemies. Instinct would guide them to abstain from flight, and content themselves with the food which they could procure by creeping or burrowing. In this manner their wings would become weakened from disuse, while their legs would acquire additional strength and development. From the continuous operation of these causes, it would happen that, in the course of a vast number of generations, the wings would become atrophied and merely

rudimentary, while the legs would increase in size and strength. The entire organism would thus become so much modified, that it could no longer be regarded as of the same species with those descendants of the original insect, which had preserved the full-sized wings and comparatively small legs of the primary type. In this manner, two diverse insects might be derived from the same ancestral stock.

Such are the modes in which natural selection, combined with the struggle for life, is imagined to have modified species, perpetuating and augmenting individual peculiarities, until they became large departures from the primary type. It will be perceived that they may have operated in two opposite directions, the one always tending to improve, the other to degrade, the primary type. The advocates of the theory admit, that immense periods of time would be required to produce, in this manner, any decided alteration in a species; but as we are quite ignorant of the length of time during which organic life may have existed on our globe, any objection on this score may be waived.

The great advantage of this theory is its accounting, in a manner so easy and natural, for the resemblances by which all organisms are linked together; while it obviates every difficulty connected with the site and mode of primary organisation in the case of the higher animals. The mutual resemblances are simply the natural consequences of a common descent; while, as every higher organism is supposed to have been organized in another a trifle lower in the scale than itself, there is no difficulty in explaining the manner in which the higher organisms were formed by degrees, even as they are now. All variation has, according to this hypothesis, taken place by slow and almost insensible gradations, under the influence of determinate laws. There has been no breach of continuity.

All has happened in an orderly and natural manner, in exactly the same way that we see the same causes operating at the present time. It is doubtless to these advantages, that the theory is indebted for the influence which it has acquired over many minds.

Its strong point, that which affords the best evidence in its favour, is the mutual resemblance among all organized beings. We find that every species is linked by many bonds of connection to every other species of the same genus.[1] Every genus is in like manner linked by several bonds of connection to every other genus of the same order, every order to every other order of the same class, and every class to every other class in the same division or sub-kingdom. The points of resemblance between species and species, are more numerous than those between genus and genus, very much more so than those between class and class. Yet there are always transitional forms, subsisting or extinct, which mark the connection between class and class, as well as between genus and genus. For example, the marsupials are a connecting link between the placental mammals and the oviparous vertebrates. The ornithorhynchus paradoxus connects the marsupials with birds. The lepidosiren is the link between reptiles and fishes. Even the wide difference between the vertebrata and the invertebrata is nearly obliterated by the amphioxus; while the still wider gulf, that seems to separate the animal from the vegetable kingdom, is bridged over by the phytozoa, whose characters are so intermediate, that naturalists are puzzled in which of the two kingdoms to arrange them.

It is freely admitted by the supporters of the theory, that the number of these transitional forms is very much smaller than would be required to render the evidence of

[1] See note R.

common descent complete. There are numerous gaps by which the chain of continuous blood-relationship is interrupted. But many of those gaps are supplied by the forms of extinct species found in the strata, and it is very reasonably argued that the geological record is so imperfect, that many more of those missing links may lie buried in inaccessible strata at the bottom of the sea, or have perished out of sight altogether. This argument may be readily admitted; for the evidences that all organic species have formed links in one great and perfect chain of organisation are so strong, that we must, on any view, suppose the many missing links in the chain to have at one time existed, although only a portion of them have been preserved in the strata.

This view is strengthened by the additions that have recently been made to our knowledge of transitional forms, by the discovery of fresh instances of such, preserved in the fossil condition. The researches of M. Gaudry in the upper miocene strata of Pikerni, in the plains of Marathon, have been particularly fruitful. They have brought to light among the quadrumana a transitional form, which links the two genera macacus and semnopithecus—among the carnivora three distinct genera which connect the hyæna with the weasel, and one which connects the wolf with the bear. (‘Quarterly Journal of the Geological Society,’ vol. xxiv. part 1.) From the slates of Solenhofen has been obtained the archæopteryx, which, having feathers and other characteristics of a bird, is in structure, particularly its tail, more akin to reptiles than any bird now alive; while in the same formation has been found a reptile more birdlike than any hitherto discovered.

It is a remarkable circumstance in connection with this view of the mutual relationship of organisms, that two animals, which have certain features of resemblance in

their adult state, have a stronger resemblance when they are quite young, and stronger still when they are in their embryo condition. It has been shown that, up to a certain point, the embryo of a vertebrate is undistinguishable from that of an invertebrate animal, and that the points of difference go on continually increasing in number and extent as the embryo advances in development. The embryo must be considerably advanced before its order can be determined. It is not till a later stage that its genus can be decided, and not till shortly before birth that its species can be ascertained. The hypothesis of a common descent, it is argued, would explain these facts better than any other that could be framed.

Another strong point in favour of the theory is the existence in many organisms of rudimentary, atrophied, or aborted members or organs. These are of no use whatever to the creatures that possess them; and it seems difficult to account for their existence otherwise than by supposing them to have existed perfect in some remote ancestor, and to have become gradually atrophied in the course of successive generations through disuse, rendered necessary or convenient by a change of external circumstances.

If, notwithstanding the imperfection of the geological record, the resemblances still subsisting among all organisms, and the transitional forms connecting order with order and class with class, are to be admitted as proofs of community of origin at all, there are no legitimate reasons for stopping short, till we arrive at a single organism as the common origin of the entire series. No stronger reason can be urged for supposing the vegetable kingdom to have had its origin in a different primary form from the animal kingdom, than might be stated for assigning different progenitors to the vertebrata and the invertebrata; for the two kingdoms are as closely linked

together by the phytozoa as are the vertebrata and invertebrata by the amphioxus. In like manner, no stronger reason can be urged for imagining the vertebrata to have had a different ancestor from the invertebrata, than might be stated for assigning different progenitors to the fishes and the reptiles, to the reptiles and the birds, or to the birds and the mammals. The same mode of argument might be carried further, even down to genera; for although the points of resemblance between genus and genus are more numerous, the evidences of transition are quite as clear in the case of the vertebrata and the invertebrata, or of the animal and vegetable kingdoms.

In whatever degree, then, transitional forms may be deemed evidences of community of origin, they are equally good for the two kingdoms as for any two genera; so that if the principle of derivation is to be admitted, it must lead to the conclusion that all organisms whatever, which now exist, or have ever existed on the earth, have been derived from a single primary form. This conclusion Mr. Darwin himself seems freely to admit. Seeing, moreover, that even the largest of existing organisms always have their origin in microscopic elements, if we are to suppose the entire series to have been derived from one original form, it may be fairly assumed to have been of microscopic size.

But while the theory thus requires our going back to a single organic form as the original whence all the others, both animal and vegetable, have been derived, it by no means follows that there must have been only a single individual wearing that primary form. It is far more probable that there may have been many such. For, seeing that, according to the theory, the variations from the first form must have taken place by very slow degrees, and the earliest modifications must for a long time have been so slight as to be almost imperceptible, even if we

suppose only one individual wearing the primary form to have been at first created, it would, according to what we observe going on at the present time, have multiplied itself without modification to many thousands of millions in a very short time. Multiplication by spontaneous fission, as being the most simple, would in all likelihood be the earliest mode of reproduction; and in the case of many of the lower organisms, fission takes place every twenty-four hours. Hence in a few years the organisms of the original type might, without any modifications whatever, or with variations of the very slightest kind, so multiply as to abound in every quarter of the globe.

This consideration removes with great ease a difficulty connected with the theory which Mr. Darwin labours to obviate in a very cumbrous manner. The difficulty is this. In very distant regions of the globe, at nearly equal degrees of north and south latitude, separated from each other by the tropics, there are found identical species mixed with others which are diverse. Now, as these species could not stand a tropical heat, there is great improbability in supposing them to have been transported by natural agency from the northern to the southern hemisphere or *vice versâ*. There would thus appear to be evidence of the same species' having had its origin in diverse and very distant regions of the globe, but agreeing pretty nearly with each other in climate, consequently in their adaptation to support the same organisms. To evade this difficulty, Mr. Darwin invokes the aid of ice to explain the transport. Recalling the evidences of glacial action furnished by many geological phenomena, he supposes what is termed by geologists, the glacial epoch, to have existed in both the northern and southern hemispheres at the same time, and to have resulted from a general lowering of the temperature of the whole globe,

arising from cosmical causes. The temperature of the tropics would thus be lowered to that of the temperate zones. The organisms both from north and south, retreating from the cold, would meet in the equatorial regions and there become commingled. On the globe's regaining its former temperature, the organisms belonging to the temperate regions would leave the tropics and return to their old haunts; but some of those originally belonging to the northern hemisphere would migrate towards the southern, and *vice versâ*; so that some of the same species would thereafter be found in both hemispheres.

It is quite a gratuitous assumption, however, that the glacial epoch was simultaneous in the two hemispheres, and had its origin in cosmical causes. The difficulties involved in such a supposition are far greater than those which it is intended to obviate; for a temperature so low as to cause the organisms of the northern and southern temperate zones to be transferred to the equator would be destructive of all equatorial species. The glacial epoch is too recent in the history of the globe to admit of the derivation of our present tropical forms from those of the temperate zones. Mr. Darwin tries to evade this objection by supposing the extreme cold to have been confined to certain parallels of longitude; but this is too obviously a figment of the fancy to be seriously entertained.

The difficulty arising out of the identity of certain species in the northern and southern temperate regions is really of no weight at all against the theory of universal derivation from one primary form; for on the supposition that the same laws prevailed at first which operate now, the primary form must have multiplied and become distributed over the whole globe, without modification, in a very brief space of time. Thus the system of derivation

from this primary form, by a series of successive slight modifications perpetuated and augmented in the offspring, would start, not from a single point or region, but almost simultaneously from every point of the surface of the globe. The modifications and variations would be greatly affected, both in kind and degree, by the external circumstances of climate, elevation, &c.; so that the derivation would follow different courses in the various regions of the earth. But where the circumstances are so much alike as they are in the northern and southern temperate zones, the derivation would to a great extent follow similar courses; so that the same derivatives from the original would be produced in both regions in nearly the same periods of time.

Had the theory no greater difficulty to encounter than this, its advocates would have little to fear. Unfortunately, however, the objections to which it is exposed are of a much more formidable kind.

It may be freely granted that, by select breeding, the variations which certain species tend to exhibit may be perpetuated and augmented. But while it is undeniable that such effects have been produced by the interference of man, there is a sad lack of evidence to show that, without such interference, they are commonly produced in nature. It might be even admitted that, in a few instances, under the influence of peculiar circumstances, originally slight variations from a normal type may have, by the isolation of the aberrant individuals, been thus perpetuated and augmented; but such exceptional cases are far short of proving this to be the ordinary course of nature, or of establishing the existence of a natural tendency to the multiplication and perpetuation of varieties.

The number of species which have exhibited any proneness to variation at all is very limited; while among

those in which it has been detected it is shown in various degrees. Compare, for example, the cat with the dog. How few are the varieties of the former compared with those of the latter animal, notwithstanding both have been domesticated for ages! It may be answered that the interference of man has been greater in the one case than in the other; so that the principle of select breeding has operated more extensively in the dog than in the cat. But this simply shows that, if animals be left to themselves, they have no tendency to perpetuate varieties, and that all those which do occur among domestic species are purely the results of human interference with their breeding. Thus, in the case of the pigeons, there has never been discovered among wild pigeons such a thing as a fantail, a pouter, a tumbler, a carrier, a runt, a barb, a turbit, or a Jacobin. These are to be found only in the dovecots of breeders. Any varieties ever found among wild pigeons are of the slightest kind, and if not segregated, they are speedily lost through the operation of the cross-breeding instinct. But were there in nature a tendency to perpetuate and augment deviations from the normal type, there should certainly be found, in some quarter of the globe, some of the above-named varieties in a wild state produced by natural selection. It cannot be answered that there has been no time for any of the slight varieties that occur among wild pigeons to have acquired by natural selection so great an amount of departure from the normal type as the tame varieties present; for six or seven years are said to be sufficient to obtain any of the latter by select breeding. If it be argued that none of the variations in question are of any advantage to the species, and are, therefore, not naturally selected, it may be answered that of the many slight variations found among wild pigeons, there should surely be some advantageous to the species, which ought, therefore, to have

been naturally selected. The improved varieties in the species ought accordingly somewhere to be found, and on their being observed it would not be difficult to reproduce them in a few years by artificial means.

Again, why is it that the turtle-dove, which is quite as much domesticated as the rock-pigeon, does not exhibit the same tendency to produce varieties? Is it not because the tendency to vary is limited to a few species? Why do not the domestic goose, duck, turkey, and peacock present the same amount of variation as the common barn-yard fowl, if it be not that this last is a more variable species than any of the others?

How is it, also, that among those animals which have been more or less domesticated, and which for the most part exhibit little tendency to variation, there sometimes appear, all of a sudden, such marked varieties as those already mentioned which have occasionally occurred among peacocks and pheasants? The suddenness of the appearance of those varieties, without any ascertainable cause, is very inimical to the doctrine of the production of varieties only by the accumulation of minute modifications. But even such marked and sudden variations, were they to occur in the wild state, would be rapidly obliterated by the crossing of the breed.

It is admitted by the supporters of the derivation theory that there is such a thing among wild animals as the cross-breeding instinct, and that it tends to obliterate accidental varieties, so preserving the normal type. Now, surely the existence of this instinct, which is nothing else than natural selection, is a sufficiently clear indication of what is the true law of nature; and its tendency, so far from being towards the perpetuation and increase of slight departures from the normal type, is towards their obliteration by continual cross-breeding. There cannot co-exist two laws of nature—two sorts of natural selection exactly

opposite to each other at one and the same time. The law must either be a tendency towards the perpetuation of varieties or the reverse. Cases may occasionally occur in which the cross-breeding instinct has not an opportunity of manifesting itself; and if aberrant pairs should be segregated by natural causes from their fellows, they might produce a race that would ultimately vary to a considerable extent from the normal type. But occurrences of this kind must be exceedingly rare. The truth is, free natural selection tends to the obliteration of varieties, and it is only artificial selection, or natural selection operating under constraining influences, that tends to their perpetuation and increase.

That such is the true law of nature is proved in a striking manner by the wonderful provisions made for the fertilization of the orchids. Mr. Darwin, in his interesting work on this subject, shows how curious, beautiful and various are the contrivances for securing the fertilization of this tribe of plants by means of insects. But he at the same time demonstrates that these provisions have been made to insure the access of the pollen, not to the stigma of the same flower on which it was formed, but to the stigma of some other flower, either on the same or a neighbouring spike. Indeed, he labours to prove this to have been the chief end for which the peculiar mode of fertilization by insects appears to have been adopted. There can be no question, therefore, that a tendency to cross-breeding, within the limits of the species, is the law of nature in the case of the orchids; and as little can it be doubted that the effect of cross-breeding is to obliterate all individual peculiarities. Thus Mr. Darwin's work on the orchids is a refutation of his own theory in regard to the character and tendency of natural selection; for it shows that the natural mode of selection is not to unite aberrant pairs, and so to

perpetuate and accumulate modifications, but to cross-breed, and so to preserve the type of the species from permanent alteration, by obliterating every individual peculiarity.

Nor are the orchids the only plants which present this peculiarity of being so constructed as to require the intervention of insects for the transfer of their pollen, and thus to prevent self-fertilization. Dr. William Ogle, in a series of papers which have appeared in the 'Popular Science Review,' 1869-70, has shown that there are flowers belonging to several other families which present a similar construction—special provision being made for the transfer, by bees and other insects, of the pollen of one flower to the stigma of another of the same plant, so as to render the fertilization of the stigma by the pollen of its own flower a rare occurrence.

On the other hand, as if to show how much in nature variety is preferred to uniformity of procedure, there are certain other flowers, in which a special provision seems to be made for self-fertilization. In Mr. Daniel Oliver's first book of Indian botany, he mentions two small-flowered campanulas of Northern India, which exhibit the curious phenomenon of having flowers of two distinct forms. Besides the flowers presenting the usual appearance characteristic of this genus, there are found on the same plant smaller flowers, about the size of coriander seeds, which never open at all, but which, nevertheless, mature abundant fertile seeds. In this case, self-fertilization is a necessity. Similar closed flowers occur in isolated species and genera belonging to widely different natural orders.

Not the least curious among the means provided for securing the fertilization of orchids by insects is the remarkable resemblance which the flowers of some of the plants of this tribe bear to insect forms. This resemblance

is doubtless intended to invite the approach of the insects imitated to those mimicking flowers. Now, surely it is much more probable that these flowers had those peculiar forms primarily impressed upon them for the purpose which the imitation is designed to serve, than that they have resulted merely from a gradual accumulation of small modifications, as Mr. Darwin supposes all such peculiarities of form to arise; for as these peculiar forms evidently subserve a rational and useful purpose, while they cannot be imagined to have arisen from any voluntary effort of the plant, to suppose that they are merely the result of the play of purely physical forces were to ignore the general principle, that every rational design must have had an intelligent designer.

But this case of imitative form presented by the orchids is only one out of many similar found in the organic world, all of which have an evident purpose, useful to the organism in which they occur. This sort of imitation has been termed mimetic analogy, and the followers of Mr. Darwin have been fain to press it into their service in support of the theory of derivation. Two cases present themselves. In the one, the object imitated has no direct relation to the mimicking organism; in the other, one species of animal imitates a different species more or less closely allied. The imitative forms of the orchids belong to the first category; and in the animal kingdom similar examples are of not unfrequent occurrence. Some insects imitate a leaf, a flower-bud, a broken twig, a stick, or a straw; while many animals are assimilated in colour to the objects by which they are usually surrounded. In all these cases the design of the imitation or assimilation is concealment, and that either for the purpose of protection from danger or of facilitating the capture of prey. The intention is in every instance obvious; and it is certainly much more reasonable

to suppose that the imitation or assimilation is the result of special design and forethought on the part of an intelligent benign Creator, providing for the welfare of the species, than that it has had its origin in accidental circumstances, and presents merely the ultimate accumulation of a long series of minute modifications carried on through countless generations.

The second case, however, is that on which the advocates of the theory of derivation mainly rely. Examples of the assimilation of one species to another species of a different but allied genus are found chiefly among birds and insects. Of its occurrence among birds instances are given by Mr. Wallace in his paper on the birds of the island of Bouru ('Proceedings of Zoological Society,' 1863.) Of its occurrence among insects, examples are cited by Mr. Bates, in his work on the 'Natural History of the River Amazon,' vol. i. p. 297. Other instances are mentioned in a paper on 'Mimetic Analogy,' by W. B. Tegetmeier, in the 'Intellectual Observer,' vol. vi. p. 307. In most of these cases the assimilation is of a weaker or less protected species to one stronger or better protected, and the resemblance is evidently designed for the safety of the former. But the whole argument of the advocates of the theory of derivation with respect to these imitations is based on the assumption that the resemblance is not original but acquired; whereas, looking to the assimilations falling under the first category, the probability that the resemblance is original and intentional is quite as great as that it has been acquired by an accumulation of small modifications.

Even granting, however, that a highly variable species may gradually acquire a resemblance to another species of a different, but allied genus, this would go no further in support of the theory than do other cases of variability. It would still have to be proved by direct experiment

that these mimicking forms are true physiological species, and not simply extreme variations of a species having the usual aspect of the genus to which it belongs. The effects of emotional impression on variable species have already been noticed. If a bantam hen could produce a chicken with a parrot's beak and feet, owing to its having been frightened by an enraged parrot, it does not seem beyond the bounds of probability that a highly variable species might, from constant association with a species of a different, but allied genus, acquire by the effects of emotional impression a general similarity to it in outward appearance—the emotional impression usually acting most powerfully on the weaker of the two species. But still, in order to render such a case available for the theory of derivation, it would have to be experimentally established that the species thus modified had become incapable of interbreeding with the primary stock, from which it was most probably derived, and this has not yet been done. When one considers the varieties of plumage and other external characters presented by the domestic fowl, some of which may be the results of emotional impression, these cases of imitative assimilation will excite the less surprise; and the probability will be strengthened, that they are merely particular and perhaps extreme cases of variation within the limits of a species.

In order further to test the theory of derivation, however, we must go to those very simple forms which, according to its principles, must have varied in the least degree from the primordial form. Take the amœba. Let us suppose the primary form to have been an organic cell, multiplying itself by spontaneous fission. It must be supposed that, among the vast multitudes undergoing this process, a pair continued to adhere together after division, and that this adhesion being found advantageous, all the others proceeding from this pair in like manner

adhered in pairs, but that among the progeny there occurred a case in which two pairs adhered; that this process continued until a good many pairs clung together; that, finding union to be strength, the adhering cells, in order to promote their mutual adhesion, thinned their walls and thickened their contents, until, after the lapse of several millions of generations, the cell-walls became atrophied and the thickened contents became blended into a gelatinous mass, forming the substance called 'sarcode,' of which the amœba is composed. We have thus got our amœba, with all its instability of form, and its capability of extemporising its limbs and stomach. But other cells, proceeding from the same original, have merely attached themselves together in long strings, and have retained their cell-walls of their primary thickness, and their cell-contents of their primary liquidity; and these have, at the end of many millions of generations, become developed into one of the confervoid algæ. Now, how happens it that the one of these two organisms manifests decided evidences of volition and voluntary motion, while the other does not? Why should the mere obliteration of the cell-walls, and the conversion of the cell-contents into a jelly, develop in the creature a will?

Again, according to the theory, among the vast numbers of amœbæ that were produced from the first lump of sarcode, some found themselves placed in water containing a certain amount of carbonate of lime in solution, and they discovered it to be advantageous to encrust themselves with this material. These amœbæ were thus, in the course of long ages, converted into foraminifera. But another set of amœbæ found themselves in water, containing in solution a minute quantity of silica, and they ascertained it to be advantageous to clothe themselves with a siliceous coating. Thus these amœbæ, at the end of a long period of time, became converted into poly-

cystina. Now, seeing these two groups of organisms had thus a common origin, how does it happen that the forms assumed by the foraminifera are so dissimilar to those fabricated by the polycystina? The difference of material affords no explanation. If it was an advantage to the polycystina to put forth long horn-like processes, why was it not also an advantage to the foraminifera? In both groups there are found spherical forms, from which, as being the simplest, all the others must, according to the theory, have been derived. But why did the derivation take so different a course in the one case from what it has followed in the other?

Again, seeing it is so great an advantage to an animal composed of sarcode to clothe itself with a shell of either silica or carbonate of lime, why do naked amœbæ continue to be produced at all? They ought, according to the theory, to have perished long ago. Why does the naked amœba of the present day, when placed in water containing either silica or carbonate of lime, never attempt to form for itself a shell, as, according to the theory, some very ancient naked amœbæ must have done? Is it because the modern amœbæ inherit in their family so great a degree of stupidity that they are unable to appreciate the advantages of a shell, or such an inveterate habit of going naked, and thrusting out a limb now here, now there, that nothing will wean them from it—not even the prospective glory of being able to form a shell that might rival in beauty some of those of their cousins the foraminifera and polycystina? Or how shall we explain the extraordinary perverseness of some of the other descendants of the primitive amœba, who, instead of wisely ensconcing themselves in a comfortable dwelling, construct an elaborate framework, and then spread themselves like a thin varnish all over the outside of it, as do the sponges?

Once more, we ought, according to the theory, to find in the course of long ages some gradual, but very decided, improvement in the breed of the foraminifera and polycystina—the more especially as these have left their history clearly written in the geological record. Now, so far from this being the case, the most ancient of the foraminifera yet discovered is the Eozoon Canadense, which occurs in the very oldest of the sedimentary rocks that have anywhere been found. Yet this patriarch of the tribe, one of the earliest descendants of the first amœba that discovered how to make a shell and the advantage of possessing one, was no mere apprentice in the art, for he had contrived to construct a dwelling far larger and more elaborate than any of those formed by the present race of foraminifera. Indeed, this family of sarcode animals seems to have at one time prevailed far more largely on the earth than it does now; and while some of the ancient forms appear to be identical with those that are still being constructed, there are mingled with them others of much larger size which have become extinct. So also with their cousins the polycystina. The fossil species are both greatly more numerous and far more perfect in their forms than the species now living, although some identical with the latter are found among the former. There is here no evidence of that improvement which the theory would lead us to expect. The age of the triumph of the foraminifera and the polycystina in the general struggle for existence has passed away, and yet we do not find the species which have survived the conflict to be in any respect better fitted to maintain their ground, than were those that have perished.

We are thus led to notice the character of the geological record generally. It is not its imperfection that is so adverse to the theory; it is the nature of the story which it tells. We learn from it that certain forms have in

past ages been very much more prevalent than they are now. For example, there was a reptilian age, in which this class of animals attained an extraordinary development. Not only were the species more numerous than at present, but the individuals attained far larger dimensions. They were much better fitted, than their degenerate representatives of the present day, to maintain the struggle for life; yet the stronger have perished and the weaker survive. So also with the megatherium, the mastodon, and other gigantic quadrupeds, well able to hold their own against rival species. If there be such an universal and hard struggle for existence as the theory assumes, why have those creatures perished, while other species of the most delicate constitution, such as the marmosets, have managed to keep alive their race to the present time? There is absolutely no proof whatever that, in this great struggle, the strongest alone have triumphed, and the weakest have gone to the wall. The very simplest and feeblest organisms of which we can form a conception are still produced in abundance, and that without their exhibiting the slightest tendency to improve their helpless condition; whereas, according to the theory, all such ought long ago to have vanished from the face of the earth.

There is another class of phenomena still more irreconcilable with the theory of derivation from a common ancestral type. Supposing it possible, by means of transitional forms, to show how the habit of reproduction by fission passed into that of gemmation, thence to hermaphroditism, and thence again to the separation of the sexes—how are we to account for such phenomena as those presented by nurse-forms and metamorphosis? The nurse-forms often produce others totally unlike themselves and then perish. Whence this dissimilarity between the parent and the offspring? It is not a case

of variation; for in every instance the series of forms through which the species passes is a closed circle; it always returns to the same starting-point. Here we have one and the same species passing through several distinct forms in succession, and not by each individual's going through all these stages, but by a change of the individual as well as of the form. How, on the principle of a common descent, are we to account for such a strange habit as this? Take even the simpler case of metamorphosis. How did the first grub learn to pass into the pupa stage, and how on attaining the pupa stage did it learn to transform itself into a winged insect? If every species be struggling with might and main to multiply itself despite of all obstacles, how are we to explain the formation of neuter insects which are sterile, as in the case of the bees, the ants, and the termites, while the neuters among the aphides are fertile? Why should these fertile neuters go on during the whole summer, producing by internal gemmation others like themselves, and why should their descendants in the ninth or tenth generation, on the approach of cold weather, change their tactics, and produce also by gemmation perfect males and females? Above all, why should this change in the nature of the progeny be capable of being deferred by prolonging the warm temperature? Why should not the neuter aphides go on producing other neuters like their immediate parents, instead of reverting to what was done by their remote progenitors of the previous year, who produced males and females preparatory to the approach of winter?

The variety of instincts—more especially of those displayed among the insect tribes—also presents an insurmountable difficulty in the way of the theory of derivation; particularly where the instincts differ, while the external forms remain similar. According to the theory,

the solitary wasps and bees and the social wasps and bees descended from the same progenitors. How then are we to account for the very great diversity of their habits and instincts, while there are no corresponding differences in their form and structure? What origin can be assigned to the strange habit of the female ichneumon fly of depositing her eggs in the bodies of living caterpillars, if the ichneumon fly and the caterpillar had a common ancestry? If all ants sprang from the same original, how are we to explain such a peculiarity as that of the Amazon and other slave-making ants, which, producing no workers themselves, are guided by instinct to invade the nests of other species that produce workers in abundance, and steal these in the pupa stage—cherishing them until their emergence into the insect state, when they perform the duties of workers to the captors, as if they had been originally bred in their nest? Whence came that other peculiar instinct of the driver ants, which, in their migrations, often cross large rivers, when the soldier-forms of the species, which are much larger and stronger than the workers, form a suspension-bridge across the water—attaching themselves together head and tail, clinging by the power of their strong jaws, and allowing the weaker workers and other forms of the species to pass over this bridge, after which the soldiers pull one another across by main force? How did the agricultural ants first acquire their still more wonderful instinct, which enables them to vie in prudence with the human race? Is the love of agricultural pursuits, so strongly manifested by a large portion of mankind, merely a case of reversion to the instincts and habits of a very remote ancestor belonging to this tribe of insects, whose innate prudence prompts them to clear a space of ground around the mouth of their nest of all vegetation, and then to sow in it the seeds of a peculiar kind of grass

which constitutes their favourite food, reaping and garnering the produce for their winter supply, and repeating the process every season?

In like manner, had all spiders sprung from one ancestral spider, by what accumulation of small modifications can we explain the peculiar habit of the water-spider, which, by means of her secreted silk, constructs under water an ellipsoidal bag, with its mouth downwards, which is both water-tight and air-tight, and which she subsequently fills with air by dragging down air-bubbles from the surface; thus converting this beautiful diving-bell into a comfortable dwelling, in the upper part of which she lays her eggs, while she herself inhabits the lower part, replenishing it from time to time with air from above, as that within becomes vitiated or exhausted?

These instincts are all useful to the species that possess them. But what could have led any animal to acquire, by slow degrees and the influence of external circumstances, such a remarkable instinct as that of the Bower-birds, which unite to form and adorn an arched bower, which has no reference to their nesting or to the rearing of their young, or any other useful purpose, but is used merely as a place of assembly and parade?

But there are other instincts and habits which are exercised only under peculiar circumstances, and at long intervals of time. If a queen-bee should perish, the neuters will select one of their class in the larval stage, and by feeding it with nourishing diet and keeping it in a warm temperature, they will cause its rudimentary reproductive organs to be developed, until it becomes a perfect queen, capable of continuing the race. The loss of a queen may not happen once in a hundred generations. How have the neuters acquired the knowledge of what is proper to be done in such an emergency? They cannot

have inherited the instinct from previous neuters, which died many years before without leaving progeny. In like manner the entrance of a slug into a hive is an accident that may not occur once in many generations of bees. Yet the neuters are never at a loss how to proceed in such a rare and untoward event. They not only kill the slug, but make a mummy of its dead body by covering it all over with a peculiar cement so as to prevent it from polluting the hive by its putrescence.

Instances also occur in which certain individuals of a species will exhibit a cunning trick, which is not shared by others of the same species. In his paper on the fertilisation of flowers already referred to, Dr. Ogle mentions the case of the scarlet-runner, as one of those flowers specially constructed to invite bees, and secure cross fertilisation by their means. Nevertheless, certain individual bees acquire the trick of piercing the nectary at the bottom, and thus abstracting the honey; so avoiding the ingenious trap laid for them, which, were they to enter the flower, and suck the honey from the mouth of the nectary, would cause them to become powdered with pollen, to be transported to some other flower of the plant. This trick is acquired by certain bees, belonging to the same hive with others who have it not, and who therefore enter the flower in the usual way. But any individual having once pierced the nectary at the bottom, will never re-enter the flower at the top. It thus appears that, even among bees, there are certain individuals more cunning than others, and that, in this case, the phenomenon is due rather to the general intelligence of the creature, than to an instinct acting certainly and mechanically, transmitted from one generation to another.

Another still more striking case is presented by what Huber records of the humble-bee. That eminent observer placed under a bell-glass about a dozen neuters of that

species, along with a piece of comb containing several cocoons. The piece was so irregular in shape that, when the bees mounted on it to impart to the larvæ the needful warmth, it became very unsteady. In this emergency a detachment of the bees placed their hind feet on the edge of the comb and their fore feet on the table, and in this constrained position, with their heads downwards, they steadied the comb, while the others mounted on it to keep the larvæ warm. The bees took this office of propping up the comb by turns. The necessity for such a proceeding as this could not have occurred except at very rare intervals indeed; yet the neuters were at no loss what course to adopt. That such an amount of intelligence could be exerted by a mere material organism, without the presence of an immaterial organizer, it would be difficult to maintain. Still more difficult would it be to contend that such an instinct as that which was here called into play was derived by the organism, in virtue of a succession of small modifications, from some more simple organism having instincts of a totally different kind.

All these and similar phenomena are easily explained, if we suppose that each species had its origin in a single organizer, or pair of organizers, specially endowed with a specific set of faculties and instincts, and that each organism in the whole line of succession, whether male, female, or neuter, contains an indefinitely extensible and divisible portion of the primary organizer thus endowed. But if we suppose all organisms whatever to have had their origin with a single created organizer, then the powers of organisation, the faculties and the instincts, which must have been conferred on that single organizer, in order to its transmitting them by inheritance to its diversified descendants, must have been so great and so various, that the created organizer could be little short of a duplicate

of the Creator himself. Or rather, seeing the instincts displayed by the descendants are many of them directly opposed the one to the other, it is quite inconceivable that they should ever have been all imparted to one and the same primary organizer.

Some of the difficulties attending the theory might at first sight seem capable of being obviated, by supposing that there may have been more than one primary organizer. Mr. Darwin himself seems disposed to admit four or five. And there is prudence in this concession; for it allows of the special appropriation of one of those primary organizers to the human race, and so avoids that shock to the feelings which most unphilosophical minds experience on being informed that man is merely a modified ape. It also relieves the theory from collision with theology; for it frees it from discrepancy with the Hebrew narrative of organic creation. If we imagine the whole vegetable kingdom to have had its origin in a single vegetable cell, that multiplied at the same rapid rate at which vegetable cells do still multiply, and that by gradual modification and agglomeration they formed in succession moulds and fungi, desmids and diatoms, confervæ and algæ, ferns and horse-tails, lichens and mosses, grasses and grains, herbs and shrubs, forest-trees and fruit-trees, the description in the Hebrew narrative would not be at variance with such a mode of procedure. The earth is commanded to cause the germination of the grass and the herb and the fruit-tree; and all that is affirmed with respect to them is that the earth brought them forth. We are left at liberty to imagine—nay, we are rather led to conclude, that the earth brought them forth then as now. Accordingly, could it be clearly proved that the above enumerated classes of plants were derived from one and the same original, and grew by slow gradations into their present forms, each successive modification having

been brought forth from the earth, there would be no discrepancy between such a natural order of events and the language of the narrative.

So also, if we suppose all the aquatic animals and birds to have had a common ancestry, some small spherule of sarcode, or some ciliated monad, still the language of the narrative would bear out the hypothesis. The command is given to the waters to bring forth abundantly the creeping (or gliding) creature which hath life, and fowl are commanded to fly above the earth in the face of the expanse of heaven. True, it is affirmed that God created great whales (or rather reptiles) and every living thing that moveth; but it is added 'which the waters brought forth abundantly,' thus indicating that God's mode of creating them was by causing the waters to bring them forth in abundance. But we may not infer, from their being first mentioned, that the great reptiles were brought forth first in order; because it is equally probable that they are mentioned first merely because of their being highest in rank of the creatures brought forth by the waters; for to this class belong the megalosaurus, the plesiosaurus, and other huge forms of the reptilian age. The term 'every gliding creature' is sufficiently comprehensive to include anything from a monad to a whale; and as the narrative does not expressly affirm that all the different sorts of gliding creatures were brought forth at one and the same time, we are at liberty to imagine the monad to have come first and the whale last, and the interval between them to have been ten thousand millions of years, or any greater period that might have been required for the latter to be derived from the former by natural selection, and the gradual accumulation of slight modifications. As to the birds, again, nothing is specially affirmed about the manner of their creation; for the clause 'which the waters brought forth abundantly' does not

apply to them. But seeing there has been found in the lithographic slate a transitional form between the bird and the reptile, it would be open to the supporters of the theory to imagine this creature, the *Archæopteryx*, to have been a modified reptile, and the more recent birds to have been modifications of that transitional form. All this might be imagined without running counter to the Hebrew narrative.

As regards the land animals again, all that the narrative avers is that God commanded the earth to bring them forth, and that God made them. From the order of enumeration's being different in the two statements, it may be inferred that there is no connection between the order in which they are named and that in which they were made. For aught that is implied in the language of the narrative, the Creator, in forming the land animals and causing the earth to bring them forth, may have proceeded by natural selection and the accumulation of small modifications from a single primordial form. In a million of years a monad may have thus been modified into a mite, in ten millions of years the mite may have been converted into a moth, and in a hundred millions of years the moth may have been transmuted into a mammoth. There is nothing in the phraseology of the narrative to hinder the adoption of such a view.

With respect to man, the narrative certainly points him out as a specialty; but as we have exhausted only three out of the four primordial forms which Mr. Darwin allows, the fourth may be assigned to man, and the theory may be thus preserved in harmony with the narrative. The supporters of the hypothesis of specific derivation then, by admitting the existence of four, only four primordial forms, may repel the assaults of the theologians, and avoid giving offence to the ladies, who always shudder at the thought of a gorilla ancestry.

But, alas! to admit four primordial forms, and more especially to give man one all to himself, is to undermine the first principles of the theory. For the whole doctrine of derivation is founded on organic affinity. Now there are transitional forms and affinities connecting the descendants of the four supposed distinct primordial forms, quite as well marked as are many of those which have been discovered between the descendants of each form among themselves. There are transitional organisms about which naturalists are continually disputing as to whether they are animals or plants; the structural affinities between the lower members of the two kingdoms are so strong, the differences so ill defined. The amphioxus unites the invertebrata to the vertebrata; the lepidosiren links the fishes to the reptiles; the ornithorhynchus connects the birds with the mammals; the gorilla unites the quadrumana to man. These affinities are quite as good indications of a common origin as are those which unite the lemurs to the monkeys, the flying-fox to the bat, or even the ass to the horse. If these transitional forms between kingdom and kingdom, class and class, are not to be explained by a common descent from a single primordial form, we must suppose the descendants of the four primordial forms to have become intermingled by extensive hybridation; and this explanation, if applied to the case of the affinities between man and the man-like apes, would be quite as little acceptable to the ladies, as the idea of their being lineal descendants of the gorilla. The structural affinities between this animal and man are so strong, that, were such affinities good evidence of community of descent in any case, it is in theirs. But if specific creation be conceded to the human species, there is no reason why it should not be granted to every other.

Once depart from the position of a single primordial

form, and there is no resting-place to be found. If we admit four, we may as well admit forty, or four hundred, or four millions. For the whole organic system is so intimately blended together, so linked by affinities crossing and re-crossing, sometimes disappearing here and re-appearing there, that, if common descent is to be regarded as the sole available explanation of those relations, Mr. Darwin is quite correct when, pushing his theory to its legitimate conclusion, he affirms his belief, 'that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed by the Creator.'

In justice to the theory, however, it must be allowed that, even when pushed to this its natural limit, it does not involve, as an absolute necessity, the derivation of man from the gorilla. It is more in accordance with the principles of the theory to suppose that the ourang-outang, the chimpanzee, the gorilla and man were all derived from a remote common ancestor now extinct—that the derivation followed, in these four cases, diverse and divergent courses, and that the links in all the four chains of derivation have, like the common ancestor itself, perished. This view is admissible as a mere hypothesis, but is altogether destitute of proof.

CHAPTER XXX.

PANGENESIS.

SINCE the foregoing chapter was written, Mr. Darwin has published his new work, entitled 'The Variation of Animals and Plants under Domestication.' In this very elaborate treatise he reiterates his theory of the derivation of species one from another by natural selection, combined with the universal struggle for existence, in its widest terms. He says, vol. i. pp. 12 and 13 :—'In considering how far the theory of natural selection may be extended, that is, in determining from how many progenitors the inhabitants of the world have descended, we may conclude that at least all the members of the same class have descended from a single ancestor. A number of organic beings are included in the same class, because they present, independently of their habits of life, the same fundamental type of structure, and because they graduate into each other. Moreover, members of the same class can, in most cases, be shown to be closely alike, at an early embryonic stage. These facts can be explained on the belief of their descent from a common form. Therefore, it may be safely admitted that all the members of the same class have descended from one progenitor. But as the members of quite distinct classes have something in common in structure, and much in common in constitution, analogy and the simplicity of the view would lead us one step further, and to infer as probable that

all living creatures have descended from a single prototype.'

That he includes the human species in this great series of derivations, Mr. Darwin leaves no room to doubt; for in treating of inherited peculiarities, and more especially of cases of atavism or reversion to the characteristics of a remote ancestor, he does not hesitate to avow his belief that certain monstrosities, which occasionally present themselves among mankind, ought to be regarded as cases of reversion to a bestial ancestry. Thus, at p. 57 of vol. ii., he says:—

'But many monstrosities can hardly be considered as the result of an arrest of development; for parts, of which no trace can be detected in the embryo, but which occur in other members of the same class of animals or plants, occasionally appear; and these may probably with truth be attributed to reversion. For instance, supernumerary mammæ, capable of secreting milk, are not extremely rare in women, and as many as five have been observed. When four are developed, they are generally arranged symmetrically on each side of the chest; and in one instance, a woman (daughter of another with supernumerary mammæ) had one mamma, which yielded milk, developed in the inguinal region. This latter case, when we remember the position of the mammæ in some of the lower animals in both the chest and inguinal region, is highly remarkable, and leads to the belief that in all cases the additional mammæ in women are due to reversion. The facts given in the last chapter, on the tendency in supernumerary digits (in the human species) to re-growth after amputation, indicate their relation to the digits of the lower vertebrate animals, and lead to the suspicion that their appearance may in some manner be connected with reversion. . . . The occasional development in man of the coccygeal vertebræ into a short and free tail, though

it thus becomes in one sense more perfectly developed, may at the same time be considered as an arrest of development, and as a case of reversion.'

In like manner he considers certain instances which he cites, of men and women who were born entirely covered with hair, as examples of reversion to the characteristics of the hairy animals from which the earlier specimens of our race were derived. The cases above mentioned, of persons born with six fingers and six toes, he traces to a more remote ancestor of the reptilian class; the bond of connection consisting in the tendency of such additional fingers and toes to grow again after amputation; this same facility of repair being exhibited by newts, whose limbs will grow again after having been amputated several times in succession. On the same principle, every case of ichthyosis occurring in the human species would fall to be regarded as a reversion to the scaly skin of that still more remote human ancestor who was a fish. In like manner, the very rare monstrosity of an infant born with a single eye in the centre of the forehead would be deemed a reversion to the human ancestor who belonged to the one-eyed entomostraca.

His having thus assigned to mankind a bestial ancestry appears to have led Mr. Darwin to form a very low estimate of the value of human life. For he plainly commends the sound sense of the inhabitants of Terra del Fuego, for following a practice which most civilised men would deem barbarous in the extreme. In vol. ii. pp. 214–215, he says:—'When the Fuegians are hard pressed by want, they kill their old women for food rather than their dogs; for, as we were assured, "Old women no use, dogs catch otters." The *same sound sense* would surely lead them to preserve their more useful dogs, when still harder pressed by famine.' He doubtless considers the Australian's killing his own infant, and making his wife

suckle in its stead a puppy of a useful breed of dogs, as, in like manner, an evidence of his practical wisdom.

Mr. Darwin seems fully sensible that his doctrine attributes to the primary rudiments of plants and animals properties of an astounding kind. He says, vol. ii. p. 61: 'The fertilised germ of one of the higher animals, subject as it is to so vast a series of changes from the germinal cell to old age, incessantly agitated by what Quatrefages calls the *tourbillon vital*, is perhaps the most wonderful object in nature. It is probable that hardly a change of any kind affects either parent without some mark being left on the germ. But, on the doctrine of reversion, as given in this chapter, the germ becomes a far more marvellous object; for, besides the visible changes to which it is subject, we must believe that it is crowded with invisible characters proper to both sexes, to both right and left sides of the body, and to a long line of male and female ancestors, separated by hundreds or even thousands of generations from the present time. And these characters, like those written on paper with invisible ink, all lie ready to be evolved under certain known or unknown conditions.'

But if the fertilised germ of one of the higher animals be thus so marvellous an object, what are we to think of Mr. Darwin's primordial cell, from which all plants and all animals, including man, have sprung? What an amazing number of properties and powers must have lain hid within the membranous wall of that single microscopically minute cell! What diversities of formative force! what varieties, and contrarieties of instinct! what latent metaphysical qualities and powers!

By far the larger proportion of Mr. Darwin's two bulky volumes is devoted to the setting forth of an immense accumulation of facts and phenomena, tending to establish these two points: 1st. That certain species of plants and

animals have a larger or smaller amount of variability, in virtue of which they naturally tend, in slight degrees, to depart from the standard type of their specific forms; and 2ndly. That mankind, by taking advantage of this tendency, may accumulate such variations to a very great extent, and thus ultimately produce forms extremely unlike the standard specific form from which they were originally derived. These two points he establishes clearly and satisfactorily, with a superabundance of evidence.

It cannot, however, be conceded to him that, by all this immense labour and industry, he has in the least degree enhanced the probability of his main theory—the derivation of species one from another by natural selection combined with the struggle for existence. On the contrary, he has rather damaged it than otherwise. There are two most important points which he has utterly failed to establish. These are, 1st. That the modifications of structure effected by man's interference are real improvements on the organism—beneficial to the organic being itself, enabling it better to maintain its ground in the universal struggle for existence, or raising it from a lower to a higher grade in the organic scale. 2ndly. That there ever has been, within the historic period, such a thing observed in nature as the formation of a higher from a lower species by natural selection, by the preservation, through select breeding, of the most perfect specimens of each species, until it ultimately became a higher species.

There is a certain amount of deceptiveness (doubtless unintentional on the part of Mr. Darwin) in the language he applies to the modifications of structure effected by human interference; for he very generally designates these alterations by the term 'improvements.' He certainly admits that these changes of structure or appearance merely render the organism more subservient to the purposes of

the breeder, or more pleasing to his fancy or his palate, or more conducive to his gains. But amid the continual reiterations of the word 'improvement' the reader is apt to lose sight of this qualification of the term, and to be misled into the conclusion that man's select breeding produces changes of structure beneficial to the organic being itself, raising it to a higher grade in the organic scale. Now the contrary is the real truth, because, while man's select breeding operates beneficially for himself, and is pursued for this sole purpose, it, in the great majority of cases, operates to the detriment of the organic being which is made the subject of his experiments. For the usual result is that one particular part, organ, or quality is abnormally developed at the expense of the others; so overturning that perfect balance which is naturally established in the wild species, and rendering the domesticated plant or animal more and more dependent on human aid and skill for preserving its existence in its altered state; insomuch that, in many cases, were the domestic varieties left to maintain the struggle for existence with the wild species, they would inevitably perish.

It hence arises that, in all domesticated varieties, there is a constant tendency to revert to the wild original type; so that the human breeder has to maintain a perpetual struggle against natural selection, in order to preserve his abnormal breeds. Mr. Darwin himself allows that, without the closest attention on the part of the breeder, no accumulation of small modifications could ever take place. Speaking of the slightness of the variations in which modified races have had their origin, he says, vol. ii. p. 406: 'Such variations will never be accumulated when an animal or plant is not closely observed, or much valued, or kept in large numbers.' Certainly they will not; and this for the simple reason, that the cross-breeding instinct in animals, and the provisions made for insuring

cross-breeding among plants, operate so powerfully in the obliteration of all individual peculiarities, that the normal type of the species is constantly preserved. Hence it happens that none of those peculiar forms which have been produced by human interference are ever found in nature, and save for human agency would never have existed at all. The evidence therefore, so far as it goes, tends to show that natural selection acts in a manner the very reverse of that in which it is alleged to operate on Mr. Darwin's hypothesis of the transmutation of species, by the accumulation of small modifications through immeasurably long intervals of time.

When Mr. Darwin or his followers are challenged to produce a single example of the conversion of a lower into a higher species by natural selection within the historic period, their answer has always been, that the time is too short; the historic period being a mere span in comparison with the enormous length of the geological epochs. But the facts brought forward by Mr. Darwin in his new treatise tend to undermine that argument; for they show to how very great an amount small modifications may be accumulated by human agency within a comparatively short period; ending in the formation of varieties, differing from each other and their wild original type more than many species differ one from another in nature.

The most curious, and what will be deemed by many the most interesting part of Mr. Darwin's new work, however, is that in which he endeavours to account for all the phenomena of variation, reversion &c., by a fresh hypothesis, which he terms 'Pangenesis.' This new theory he promulgates at p. 374 of vol. ii. in the following terms:—

'It is almost universally admitted that cells, or the units of the body, propagate themselves by self-division, or proliferation; retaining the same nature, and ultimately becoming converted into the various tissues and sub-

stances of the body. But besides these means of increase, I assume that cells, before their conversion into completely passive or "formed material," throw off minute granules or atoms, which circulate freely throughout the system, and, when supplied with proper nutriment, multiply by self-division, subsequently becoming developed into cells like those from which they were derived. These granules, for the sake of distinctness, may be called "cell-gemmules," or, as the cellular theory is not fully established, simply "gemmules." They are supposed to be transmitted from the parents to the offspring, and are generally developed in the generation which immediately succeeds, but are often transmitted in a dormant state, during many generations, and are then developed. Their development is supposed to depend on their union with other partially developed cells or gemmules which precede them in the regular course of growth. . . . Gemmules are supposed to be thrown off by every cell or unit, not only during the adult state but during all the stages of development. Lastly, I assume that the gemmules, in their dormant state, have a mutual affinity for each other, leading to their aggregation either into buds, or into the sexual elements. Hence, speaking strictly, it is not the reproductive elements nor the buds which generate new organisms, but the cells themselves throughout the body. These assumptions constitute the provisional hypothesis which I have called "Pangenesis." Nearly similar views have been propounded, as I find, by other authors, more especially by Mr. Herbert Spencer, but they are here modified and amplified.'

To meet the objection, which he anticipates might be urged against these supposed gemmules, by reason of their extreme minuteness, Mr. Darwin remarks, p. 404: 'These almost infinitely numerous and minute gemmules (proceeding from every part of the organism) must be

included in each bud, ovule, spermatozoon, and pollen-grain. Such an admission will be declared impossible. But, as previously remarked, number and size are only relative difficulties, and the eggs or seeds produced by certain animals or plants are so numerous, that they cannot be grasped by the intellect.

'The organic particles, with which the wind is tainted over miles of space by certain offensive animals, must be infinitely minute and numerous; yet they strongly affect the olfactory nerves. An analogy more perfect is afforded by the contagious particles of certain diseases, which are so minute that they float in the atmosphere and adhere to smooth paper; yet we know how largely they increase within the human body, and how powerfully they act. Independent organisms exist which are barely visible under the highest powers of our recently improved microscopes, and which are probably fully as large as the cells or units of one of the higher animals; yet these organisms no doubt reproduce themselves by germs of extreme minuteness relatively to their own minute size. Hence the difficulty, which at first appears insurmountable, of believing in the existence of gemmules so numerous and so small as they must be, according to our hypothesis, has really little weight.'

Here Mr. Darwin, with the skill of a special pleader, has selected for answer by anticipation that objection which is perhaps, of all others, the most easily obviated. There are some, however, of a graver aspect, which cannot be so readily met. In the first place, the existence of these gemmules is, and ever must remain, purely hypothetical. Their actual existence can never by any means be demonstrated. In the second place, this hypothesis is on the one hand defective and on the other redundant. It is defective, inasmuch as it altogether ignores the existence of the non-material organizer, in which the

property of life resides, and which is the cause of all the metaphysical phenomena displayed by organic beings. It is redundant, because, if the existence of this non-material organizer be admitted, the phenomena of inheritance and reversion can be quite well explained without the assumption of gemmules at all. This hypothesis of gemmules is, in fact, pure materialism. It is an attempt to obviate the necessity for assuming the existence of a non-material being in any organism. To place this point in a clear light, let us take the example of the descent of hereditary qualities given by Mr. Darwin himself. In vol. ii. at p. 95 he says:—'Lord Orford crossed his famous stud of greyhounds once with the bull-dogs, which breed was chosen from being deficient in scenting powers, and from having what was wanted, courage and perseverance. In the course of six or seven generations, all traces of the external form of the bull-dog were eliminated; but courage and perseverance remained.'

Now, to explain such a case as this, it is evidently needful to assume that the qualities of courage and perseverance were possessed by the gemmules proceeding from the brain of the ancestral bull-dog. But if courage and perseverance may thus be inherent in certain minute assemblages of mere material atoms, and be communicated by them from one organism to another, like a contagious disease, then life itself, reason, imagination, and judgment may in like manner be all qualities of minute assemblages of mere material atoms, so that the hypothesis of the existence of a non-material organizer, or of a rational mind or spirit, would become superfluous.

But if the existence of the non-material organizer, with the qualities assigned to it in a previous chapter, be admitted, the assumption of the gemmules becomes in its turn superfluous. The courage and perseverance inherited by Lord Orford's greyhounds from the cross with

a bull-dog, would be explained by the hypothesis, that an indefinitely expansible and divisible portion of the non-material organizer of the bull-dog was transmitted to his progeny, and that it was to this, and not to the mere material atoms, that the metaphysical qualities of courage and perseverance were attached. The same reasoning of course applies with still greater force to the inheritance of metaphysical and moral qualities in the human species, and to cases of reversion of the same.

Apart, however, from metaphysical qualities, the hypothesis of gemmules is defective. Mr. Darwin himself admits that the cell-theory is not established in the case of the animal kingdom. He might have gone further, and confessed that, by some of the most eminent naturalists, the applicability of the cell theory to several of the phenomena occurring in the development of animal organisms is utterly denied. The cases to which it is inapplicable have been already noticed. Such phenomena as are presented by the sarcode animals, especially their formation of vacuoles, seem inexplicable on this hypothesis. Neither does it appear possible to apply it to those cases, occurring in the development of some organisms, in which void spaces are formed and organs are developed in these; or to those other cases in which certain parts or organs are destroyed or absorbed during development, in order to make way for others. For example, how could it be applied to explain the total absorption of the tail of the tadpole, in the course of its development into a frog?

The whole of the phenomena described by Mr. Darwin under the head of variability, inheritance, reversion, &c., are easily explicable on the assumption of the existence in each organism of a non-material organizer, endowed with powers and properties conferred by an omnipotent Creator, and governed by laws devised by an omniscient mind. Grant this, and that each organizer is indefinitely divisible

and extensible, then all difficulty in the explanation of these phenomena will disappear. Deny the existence of the organizer, and assume the existence of nothing but the mere material ultimates, then, although some of the phenomena might be explained, there would always remain a large surplus utterly inexplicable. There is this great difference, moreover, between the assumption of the existence of the non-material organizer and that of Mr. Darwin's gemmules, that, while the existence of the latter can never be proved, but only remotely inferred, we have for the existence of the non-material being, in the case of the human species, the best of all evidence, the consciousness of each individual human mind, which may be regarded as the basis of all human knowledge whatever ; while, in the case of organisms lower than man, we have the evidence of the strictest possible analogy.

The hypothesis of Pangenesis leads not only to materialism, but thence onward to atheism. It would perhaps be uncharitable to accuse Mr. Darwin of either materialism or atheism: but he has propounded his theory without adverting to the logical consequences to which, if carried to its legitimate limits, it must inevitably lead. Indeed, he seems to be himself sensible, that there is some incongruity between his views and the assumption of the existence of an omnipotent and omniscient Creator. He compares the action of man, in the modification of organic forms by select breeding, to that of an architect, who should erect an edifice of stones of particular shapes, carefully selected from the heaps accumulated at the base of a precipice, some of which should be rectangular for his walls, others wedge-shaped for his arches. Mr. Darwin then concludes his treatise with the following remarkable paragraph :—

'The shape of the fragments of stone at the base of our precipice may be called accidental, but this is not strictly correct; for the shape of each depends on a long sequence

of events all obeying natural laws; on the nature of the rock, on the lines of deposition or cleavage, on the form of the mountain, which depends on its upheaval and subsequent denudation, and lastly on the storm or earthquake which threw down the fragments. But in regard to the use to which the fragments may be put, their shape may be strictly said to be accidental. And here we are led to face a great difficulty, in alluding to which I am aware that I am travelling beyond my proper province. An omniscient Creator must have foreseen every consequence which results from the laws imposed by him. But can it be reasonably maintained that the Creator intentionally ordered, if we use the words in any ordinary sense, that certain fragments of rock should assume certain shapes, so that the builder might erect his edifice? If the various laws which have determined the shape of each fragment were not predetermined for the builder's sake, can it with any greater probability be maintained that he specially ordained for the sake of the breeder each of the innumerable variations in our domestic animals and plants?—many of these variations being of no service to man, and not beneficial, far more often injurious to the creatures themselves. Did he ordain that the crop and tail feathers of the pigeon should vary, in order that the fancier might make his grotesque pouter and fan-tail breeds? Did he cause the form and mental qualities of the dog to vary, in order that a breed might be formed of indomitable ferocity, with jaws fitted to pin down the bull for man's brutal sport? But if we give up the principle in one case, if we do not admit that the variations of the primæval dog were intentionally guided in order that the greyhound, for instance, that perfect image of symmetry and vigour, might be formed, no shadow of reason can be assigned for the belief that variations alike in nature, and the result of the same general laws, which have been the

groundwork, through natural selection, of the formation of the most perfectly adapted animals in the world, man included, were intentionally and specially guided.[1] However much we may wish it, we can hardly follow Professor Asa Gray in his belief "that variation has been led along certain beneficial lines, 'like a stream' along definite and useful lines of irrigation." If we assume that each particular variation was from the beginning of all time pre-ordained, the plasticity of organisation which leads to many injurious deviations of structure, as well as that redundant power of reproduction which inevitably leads to a struggle for existence, and, as a natural consequence, to the natural selection or survival of the fittest, must appear to us superfluous laws of nature. On the other hand, an omnipotent and omniscient Creator ordains everything and foresees everything. Thus we are brought face to face with a difficulty as insoluble as is that of free-will and predestination.'

From this passage it appears to be contrary to Mr. Darwin's principles to suppose that any special sort of variability in an organism was pre-ordained by an intelligent Creator, or that the formation of every species of plant and animal from a primordial cell, by the accumulation of small modifications, throughout countless ages, caused by the continuous operation of natural selection, aided by the universal struggle for existence, was 'intentionally and specially guided,' that is, directed and superintended by an intelligent Mind. On the other hand, he allows that, if there do exist an omnipotent and omniscient Creator, He 'must ordain everything and foresee

[1] While penning this sentence, Mr. Darwin seems to have forgotten the structure of the orchids and the cases of imitative assimilation among animals, in all of which design and intention are so manifest, that it appears impossible to exclude the idea of intelligent guidance without maintaining that the ultimates of matter are themselves intelligent, and capable of assuming these forms knowingly and of set purpose.

everything.' Now, although Mr. Darwin may not intend that such a conclusion should be drawn from his premisses, the logical deduction is, that, if his principles are to be maintained, we must abandon the idea of the existence of an omnipotent and omniscient Creator. Indeed, if his theories be carried to their legitimate conclusion, such an assumption as that of a creating and superintending Intelligence becomes superfluous.

Grant Mr. Darwin his gemmules, endow them with all the powers and properties which he must assign to them, in order to their becoming available for explaining the phenomena, confer on them the needful complex mutual affinities, the vast varieties of formative force, the faculty of possessing and transmitting life, and such metaphysical qualities as courage and perseverance, consequently every other metaphysical or moral quality—and then, indeed, all idea of a superintending all-wise Intelligence becomes unnecessary, and we at once rid ourselves of any puzzle arising out of the predetermination and foresight of such a supposititious Being. Grant Mr. Darwin, moreover, his primordial cell, from which all organisms, including man, have been derived by the accumulation of small modifications, during immeasurable epochs of time, through natural selection, without any intentional or special guidance, and the idea of creation or a Creator becomes in like manner superfluous. For, since it can never be proved that the material ultimates may not have existed always, they may also have always possessed certain mutual affinities; and when, at some very remote epoch in the eternal past, a certain number of those ultimates, in virtue of their affinities, came into casual conjunction, they may have, as a consequence of their union, acquired certain tremulous motions which we call life, and thus have constituted the primordial living cell. Seeing that, according to Mr. Darwin, life, courage, per-

severance, &c., are qualities possessed by a minute assemblage of mere material ultimates, and transmissible by them to other similar assemblages, is it necessary to invoke the aid of a Creator to breathe, as he phrases it, into his primordial cell the breath of life? If life be a mere form of motion, (and being, according to Mr. Darwin, a property or affection of the material ultimates alone, it can be nothing else than a species of motion, resembling the vibratory motion of heat,) may it not be a mere conversion from some other species of motion, which the material ultimates may have possessed from all eternity?

By thus carrying out Mr. Darwin's theories to their legitimate limits, we should at once free ourselves, not only from all difficulty in reconciling the variations of organisms with the predeterminations and prescience of an omnipotent and omniscient Creator, but also of the kindred difficulty, to which he refers, of reconciling predestination with free-will.

The truth is, neither the one difficulty nor the other has any real existence. The puzzle finds a place only in minds mystified by false preconceptions. The slight tendency to variation exhibited by species was doubtless pre-ordained by the Creator for the purpose, not of enabling men, by select breeding and the accumulation of small modifications, to produce monstrosities, or even beautiful varieties, for their own pleasure or convenience, but of imparting to each individual organic being peculiarities more or less marked, by which it might be distinguished from every other subsisting individual in the same species; a purpose which Mr. Darwin himself must allow to have been wise and good. The queen-bee doubtless perceives among the drones in a hive as much individual difference as a young lady discerns among the

beaus in a ball-room, and discriminates not less shrewdly in the choice of her partner.

As regards free-will and predestination, again, the conferring of free-will on a created being (if by that term we understand the freeing of the created will from the restraints of all necessary or indefeisible law, and constituting it a law unto itself), was, on the part of the Creator, a voluntary renunciation of both predetermination and prescience to a limited extent, in so far as regards the absolutely free determinations of such a created will.[1]

[1] Those who may wish to unravel this latter puzzle may obtain some little help from perusing an article 'On the Divine Government,' in *The Journal of Sacred Literature*, for January 1868.

CHAPTER XXXI.

NATURAL SELECTION.—ITS DIFFICULTIES.

SINCE the publication of Mr. Darwin's work on 'Animals and Plants under Domestication,' there has appeared in the serial named 'The Month,' Nos. 61, 62, and 63, a clever essay, under the title 'Difficulties of the Theory of Natural Selection,' in which, while all credit is allowed to that hypothesis for the facilities which it offers towards explaining certain phenomena, the objections to its universal or even general application to account for the origin of species are ably urged.

The defects of the theory are shown to be its inability to explain, 1st, the beginnings of variation; 2nd, the origin of identical structures in very diverse species and distant localities; 3rd, the sudden development of remarkable variations; 4th, the absence in wild species of variations like those occurring under domestication; 5th, the definiteness of the limits of variation; 6th, the disagreement of the doctrine of minute and gradual variation with recent zoological and anatomical discoveries; 7th, the fewness of existing and fossil transitional forms; 8th, the extent of geographical change during the existence of the present fauna which the theory requires; 9th, the barrenness of hybrids; 10th, reversion to the wild type; and 11th, its failure to account for several other phenomena.

The illustrative cases adduced under the first head are, 1st, the long neck and front legs of the giraffe; 2nd, the

mimicry of one species by another; 3rd, the position of the eyes in flat fishes; 4th, the first formation of limbs and their adaptation to particular uses; 5th, the development of baleen (whalebone) in the palate of whales; 6th, the peculiar organs of the sea-urchins and their mode of development; 7th, the formation of mammary glands; 8th, the cutaneous projections in the cheeks of the male ourang-outang: 9th, the rattle of the rattlesnake, and the expanding neck of the cobra.

As respects the giraffe, it is argued that the theory of natural selection combined with the struggle for existence and the survival of the fittest fails to explain its long neck and fore-legs; because among the numerous allied animals inhabiting the same regions, under the same conditions, none have acquired similar peculiarities; while the giraffe is quite as able as any of these to roam in search of food during periods of scarcity. The lengthening of the neck and fore-legs, supposing them to have been a superinduced peculiarity, must have entailed some augmentation of bulk and mass, requiring an increase of nourishment; an effect tending to neutralise the facility for obtaining food afforded by the modification of form; and as strength does not increase in nearly the same ratio as bulk, it is doubtful how far this peculiarity would aid its possessor in the struggle for existence, or whether the giraffes having the longest necks and fore-legs would be thus preserved by natural selection, under the law of the survival of the fittest.

As the theory assumes a constant tendency to variation in indefinite directions, it is argued that such a tendency would be unlikely in any case to pursue a course so definite as to culminate in the mimicry of one species by another, far less in the mimicry by an animal of the appearance of some wholly foreign object; as, for example, the resemblance of some insects to a leaf or a twig. In

this last case, it is vain to build any argument on the probability of a community of descent between the insect and the leaf or twig.

It is a postulate in the theory that all variations arise by slow degrees; but it is pointed out that the transfer of both eyes to the same side of the head in flat fishes by a gradual transit is in the highest degree improbable, especially as there are no examples of transitional forms in which the journey has been accomplished only half-way.

In like manner, the lowest vertebrates being limbless, the theory fails to explain the first origin of limbs in these classes; for it requires us to suppose them to have started from infinitesimally minute beginnings. The prehensile tail in certain arboreal monkeys, while most useful in climbing trees, could not in its rudimentary stages lend any aid to the preservation of the species, so as to insure its conservation and increase by natural selection; while many arboreal monkeys manage to live quite well without this fifth hand, and show no tendency to modify their tails towards the prehensile type. So also, in the case of the baleen of whales, while its usefulness in its perfect state must be acknowledged, yet in its incipient stages, through which, according to the theory, it must have passed, it could contribute nothing to the welfare of the species, so as to render it a feature likely to be adapted for further development and perpetuation by natural selection. The appendages in sea-urchins called *pedicellariæ*, consisting of a long slender stalk ending in three short limbs and supported by an internal skeleton, may be useful in their fully developed state, but in a rudimentary stage would be altogether useless, and so unworthy of conservation for further development by the blind force of natural selection acting without fore-knowledge of their eventual utility. The metagenesis of the

sea-urchin and other crustaceans is likewise inexplicable by the theory; so also is the case of certain insects, which in passing from the grub to the perfect stage, instead of undergoing the usual metamorphosis, develop certain patches of tissue, which coalesce to form the adult. Neither can the theory explain the development of mammary glands by small beginnings in an animal possessing none, seeing they would be useless in their rudimentary stage; far less can it account for their development in young males, in which they are never used at all. The cutaneous developments on the cheek of the ourang-outang could contribute nothing to the welfare of the species, seeing the females do not select their mates. The rattle of the rattlesnake and the expanding neck of the cobra, by giving warning, must rather tend to facilitate the escape of prey from those serpents than to help them in its seizure, while they could not in their rudimentary stage produce any effect either one way or other; so that selection was most unlikely to seize on such peculiarities for increase and conservation.

Under the second head—that of the origin of identical structures in very diverse species and distant localities—there is cited the case of the Thylacine, or Tasmanian wolf, whose teeth are identical in structure with those of the dog, while in other respects, particularly in being pouched, it is connected with the kangaroo and other marsupials. Likewise the identity of structure in the back teeth of insectivorous animals whether pouched or not, as also the mammalian character of the cetacea, notwithstanding their dissimilarity in other respects to terrestrial mammals, combined with their resemblance in certain particulars, not resulting from similarity of habit, to the extinct great marine reptiles the ichthyosauri, are all inexplicable by the theory. Nor less so is the case of the bats, which, while standing high among the mamma-

lia, resemble in their back and breast bones, their hind limbs, and especially their wings, the extinct Pterodactyles which were reptiles—consequently far removed from them in the zoological scale. The crustaceans are in like manner widely separated in the scale from the bivalve mollusks; yet certain species of the former possess adductor muscles connecting their two sides like those by which the mollusca close the valves of their shells. Certain of the polyzoa or bryozoa (more especially the sertularia) exhibit curious organs—called bird's heads processes, corresponding closely with the pedicellariæ of the Echinus. Yet those two animals stand far apart in the scale of being. The placenta of mammalians disappears from the birds and reptiles, yet reappears in certain sharks, and even in the lowly ascidians or sea-squirts. Air sacks are common to birds and certain winged insects, notwithstanding the immense interval between those two classes. Birds and reptiles have many points of resemblance, in so much that the supporters of the theory of natural selection hold the former to have been derived from the latter. But ordinary birds agree most nearly with the fossil pterodactyles which must be deemed their ancestors; while struthious birds (ostriches, emues, &c.) agree most nearly with the fossil dinosauria (such as the Iguanodon and its allies), and must therefore be held to have sprung from them. Yet the ordinary and the struthious birds agree more nearly with each other than with either of their supposed reptilian progenitors, or than these last agree together. If all birds had the same reptile origin, why do one set most resemble the dinosaurians, and another set the pterodactyles? But if they sprung from those two diverse reptilian ancestors, why should the two sets of birds resemble each other so much as they do? Again, there are prehensile tails to be found not only among the quadrumana, but also among the carnivora, the rodentia, the edentata, and the marsu-

pialia. The windpipe of the sloth resembles that of birds, and the ant-eater has a bird-like gizzard. There is a similarity in the crown of the teeth in certain seals, sharks, and extinct cetaceans. All these cases of resemblance or even identity of structure are regarded as adverse to the theory—the explanation of their being due to a common ancestry, and the operation of natural selection being highly improbable.

Again, as respects similarity of structure arising in distant localities, the case is cited, which was first noticed by Mr. Wallace, of an Oriole in the island of Bouru which mimics a honeysucker; while in the adjacent island of Ceram another species of Oriole mimics another species of honeysucker. The probabilities against the supposition that this double mimicry, occurring in the same genus, arose by natural selection operating for a very long time on minute shades of variation, until the mimicry in both cases became complete, are very great indeed. So also with respect to the peculiarity of wing observed by Mr. Wallace in the butterflies of the island of Celebes, which that naturalist supposes to have been caused by the abundance at some remote period of insectivorous creatures in that island, it is pointed out that the help supposed to be given to flight by the peculiarity in question is equally hypothetical with the former abundance of insectivorous animals in the island, which has at present no more than an ordinary share. It is urged that modifications in insects, particularly in brilliancy of colour, follow an increase in the warmth of the climate, and do not depend on a decrease in the number of insectivorous birds, which might admit of the survival of these more gaudy species; while the birds are not only as numerous and destructive in the warmer climates, but exhibit a similar increase in brilliancy of colour. Further, as regards mimicry, it is argued that protection of the weaker mimicking creature

cannot be the origin of this peculiarity; for it occurs where no such protection is acquired, and it is very often absent where the protection it might afford would be highly beneficial. Other insects and other birds than those in which mimickry is seen would find in it an immense advantage; yet natural selection has not in their case fostered any such tendency.

Under the third head—that of the sudden instead of gradual appearance of remarkable variations—there are cited several examples of the effects of change of climate, food, and other outward circumstances in dogs, cats, pigs, cattle, rabbits, turkeys, &c., all produced suddenly or with great rapidity. Oyster spat, taken from the shores of England and placed in the Mediterranean, develops into oysters with the peculiarities of those originally bred in that sea. Certain varieties of cattle, sheep, dogs, fowls, pigeons, and ducks, have in like manner appeared all of a sudden among domestic breeds, and the remarkable case of the bronze variety of the peacock previously mentioned in this work is also cited. A similar suddenness of variation which has been observed among vegetables, particularly in maize and the kale tribe, is likewise noticed, and the curious circumstance that twenty-nine kinds of American trees differ from their nearest European allies in the same particulars—namely, in having their leaves less toothed, their buds and seeds smaller, and their branchlets fewer. All these cases, it is contended, are adverse to the notion of the accumulation of small modifications, by natural selection.

Under the fourth head—the difference between the variations occurring in the wild and domestic states—there is cited the case of the wild drake, which has never been known in any individual instance to desert its monogamous habit; whereas the tame drake is decidedly polygamous. The parts little used in domestic animals, such

as the wings of tame birds and fowls, do not become aborted or rudimentary although they may be reduced in size and weight. Where rudimentary parts do occur, Mr. Darwin asserts that in domestic animals they arise from a sudden arrest of development, but in wild animals slowly. This, however, is shown to be mere assertion without proof. Domestication itself favours a tendency to variation which may be wholly absent in the wild individuals of the same species, because it alters so much the circumstances in which the animal is placed; while in selecting animals for domestication, those were probably chosen which exhibited the greatest natural proneness to vary.

Under the fifth head—the definiteness of variability—it is shown that further variation in certain desired directions among domestic animals is in some instances extremely difficult, in others impossible. Neither is the degree of variability attainable in one species any criterion of what may be reached in another. It has not been found possible to increase the number of feathers in the tail of the fantail pigeon beyond a certain number, nor to develop the crop of the pouter beyond a certain size. While it has been found possible to develop the tendency to have feathers behind the feet, it has not been found possible to render pigeons web-footed, or to prolong any of their tail-feathers like those of the Trogons. There have been no beginnings of which select breeding could avail itself for either of those purposes. The very small extent to which the goose, peacock, and guinea-fowl have been made to vary under domestication, as compared with what has been accomplished in the dog, cat, domestic fowl, and pigeon is noticed; and it is pointed out that, had the three first-named genera shown the same proneness to vary as the others, it would have attracted attention and been seized hold of by breeders. The peacock,

in particular, has shown no varieties but the japanned and the white, which are of sudden manifestation; but no minute variations have occurred in the common peacock of which the breeder could avail himself to produce a new variety by select breeding. The guinea-fowl has shown itself persistent under great changes of climate and conditions. It is thus proved to be an unwarranted assumption that all wild animals have the same capacity for variation as those under domestication. If the tendency be limited in the latter it must be more so in the former. It is fallacious to argue that because no two species of the same genus differ more than do extreme varieties of certain domestic animals, the variation must have had in both cases the same mode of origin, or that because certain domestic animals have varied, all natural species must be capable of variation to a similar extent. Against the indefiniteness of the proneness to variation is urged the fact that some animals, when placed in the most favourable circumstances for promoting variation, similar to those which so conspicuously affect domestic animals, have nevertheless not varied—not even so much as some wild animals have been known to vary. The instability of variations produced under domestication, and the tendency to revert to the wild type are also urged in favour of the definiteness of their variability.

Under the sixth head—the unfavourable bearing of recent zoological and anatomical discoveries on the theory of minute and gradual modification—are cited cases, in which it has been proved that certain links, at one time thought to connect diverse animals, have been found on further investigation to have a different character. Thus the Aye-aye (Cheiromys Madagascariensis), while admitted to be connected with the lemurs and apes, was at one time supposed to form a connecting link with the squirrels; but further examination has shown it to be not more

closely related to that tribe than are other lemurs. The connection at one time supposed to exist between bats and birds, cetaceans and fishes is now ascertained to be merely superficial, there being in neither case any real affinity. The relation between batrachians and reptiles has been shown to be less intimate than that between batrachians and fishes. The theory requires us to suppose the progress of organization to have been from the more general to the more special; whereas some fossils found in recent formations are more general in their organization than others found in more ancient strata; while other fossil forms are more specialized than some existing allied species. Thus the Macrauchenia found in recent strata is more generalized as respects the structure of the hind foot than some forms of hoofed animals, such as the Palæotherium and Anaplotherium of the Eocene strata. The fossil Glyptodon is more specialized than any existing Armadillo, and the fossil Machairodos, or sabre-toothed tiger, is more specialized, as respects its dentition, than any existing carnivorous animal.

Under the seventh head—the fewness of transitional forms—is noticed the absence of any such between the Dinosaurians and the struthious birds. While the Archæopteryx seems to be a link between the Pterodactyles and ordinary birds, there is no evidence of a gradual passage from the Pterodactyle to the Archæopteryx, or from the latter to ordinary birds. Yet the Archæopteryx occurs earlier in the strata than any Dinosaurians, and any incipient transition from the Pterodactyle would have had as good a chance of being preserved in the strata as these animals themselves. (It should be remembered, however, that the Archæopteryx was a very recent discovery.) The strata offer no examples of the line of derivation which culminated in the whale or the bat. Moreover some of the fossil forms which were at one time

supposed to illustrate gradual transition, have by further investigation been shown to be unavailing for the purpose. Thus the Labyrinthodonts were at one time thought to illustrate the gradual segmentation and ossification of the spine in vertebrates; but some of the forms which occur earliest have completely developed vertebræ; so that those with imperfectly formed back-bones are now regarded as having been immature or larval forms. So also among the Trilobites, which were at one time thought to illustrate the gradual development of eyes, there have been found perfect eyes among those which occur earliest in the strata. Finally, it is argued that the absent transitional forms and missing links in the chain of evidence, necessary to establish the gradual derivation of species from species, had quite as good a chance of preservation in the strata as any other specimens; so that their absence is a strong presumption of their non-existence.

(There is no great force in this argument based on the absence of transitional forms in the strata; for whatever view be taken of the origin of species, there exist so great a number of transitional forms, both recent and fossil, as to show that in nature there is seldom a sudden passage from one form to another very diverse, but that, on the contrary, almost all organisms are linked together by relations or analogies obvious to the discerning eye.)

Under the eighth head—the extent of geographical change during the existence of the present fauna required by the theory—it is pointed out that the resemblance between the fresh-water fishes of India and Africa renders it necessary to suppose these two countries to have been at one time so intimately connected as to involve intercommingling of their fresh waters; while for the same reason Africa and South America must be supposed to have been similarly connected; because Africa has also fresh-water fish similar to those of South America. Yet there is a

total dissimilarity between the Indian and South American forms. (This fact, however, might be explained by supposing one set of African rivers to have been at one time connected with those of India, and another set with those of South America without subsequent intercommunication between those two sets of African rivers.) Again, certain lizards of the Iguana tribe are found in Madagascar and South America, but are absent from Africa and India; yet the South American fresh-water fishes have not been found in Madagascar. This island has also certain insectivorous genera, belonging to a group of which the only other member is found in Cuba and Hayti. But had the West Indies been ever united with Madagascar, it must have been before this island possessed its lemurs, of which tribe none are found in the West Indies. So also South America and Australia are connected by their Marsupial fauna and also by their batrachians; but the animals of this last group existing in South-western America resemble those found in Europe. These difficulties could be evaded only by supposing similar organisms to have had their origin in widely different localities.

Under the ninth head—the sterility of Hybrids between distinct species, as contrasted with the fertility of the offspring of very divergent varieties of the same species—the insufficiency of Mr. Darwin's attempts to obviate this difficulty is pointed out.

Under the tenth head—the reversion of varieties to the wild type—it is shown that Mr. Darwin, in his endeavours to elude this objection, has proved no more than that it is not every breed that will in a few years revert to the primary stock; but it is answered that animals may differ in the rapidity of reversion as much as they do in the tendency to variation. Some alleged cases of reversion, on which Mr. Darwin tries to establish an ancestral relationship, are shown to be fallacious.

Under the eleventh head—the irreconcilability of the theory with other phenomena—those of homology or resemblance of parts are specially adduced, and attention is called to the three cases of serial, bilateral, and vertical homology. It is argued that Mr. Darwin's notion of a law of correlation is insufficient to account for these resemblances—more especially for the sudden passage from one species of homology to another in the same creature, as in the case of the star-fishes which in the larval state present bilateral homology, which is characteristic of the highest animals; while in the adult condition they assume radial homology, which is characteristic of the lowest. It is contended that the facts presented by homology are explicable only on the supposition of an innate tendency in each order of being to develop its own peculiar resemblances in its different parts, while there is no trace of the derivation of one set of homologies from another.

The remainder of the essay is devoted to some just remarks on the inadequacy of the doctrine of natural selection to account for the origin of moral perceptions and intellectual qualities, on the supposition of the derivation of man from any of the lower animals, and it concludes with some sharp criticisms on Mr. Darwin's new hypothesis of Pangenesis, and animadversions on its atheistic tendencies.

It will be perceived that, while the line of argument, pursued in the essay which has been thus analyzed, differs from that which had been adopted in the immediately preceding parts of this work, the conclusion to which it leads is the same—namely, that the theory of Natural Selection, operating in conjunction with the struggle for life and the survival of the fittest, is unable to account for the origin of organic species, and for many phenomena presented by the organic world—both the existing and the extinct.

On the other hand, it may be confidently affirmed that there are not, in the organic world, any phenomena, in so far as these have fallen under human observation, of which a satisfactory explanation is not furnished by the assumption of there being, in every organism, a non-material organizer, endowed by the Creator with penetrability, indefinite divisibility, indefinite extensibility, and specific powers, faculties, instincts, and propensities, in virtue of which it elaborates and maintains the material structure in which it dwells, and exhibits phenomena altogether unlike those presented by inorganic matter. There is indeed no alternative whatever between the admission of such a non-material organizer in each organism, and the regarding life as a temporary property of matter itself—an opinion which is pure and unmitigated materialism, disguise it as we may.

CHAPTER XXXII.

SPECIFIC CREATION.

THE theory of specific creation, while free from most of the objections to which the doctrine of organic derivation is open, has nevertheless to encounter serious difficulties of its own. According to this theory, during the creative epochs (which may have been of any length whatever that the evidence renders it needful to assume) the Deity created in succession many millions of organizers—immaterial beings endowed with indefinite extensibility and divisibility, penetrability, the power of combination, and the faculty of organization. With this last they were gifted in various degrees—the faculty being diversified in an almost infinite number of ways. Each organizer had its own particular part assigned to it; but all were subjected to general laws from which they could never depart. Some were restricted to the construction of an organism of one determinate form—others to the fabrication of organisms of two determinate forms. The faculties of a third set were extended to the elaboration of several, but still a definite number, of forms. To a fourth was given the power to organize forms with a tendency to variation within certain limits.

Besides the organizing faculty, a great number of these organizers were endowed with other faculties and powers, such as volition, consciousness, perception, imagination, memory, instinct, reason. These were conferred in various

proportions and with diverse modifications. Instinct more especially was greatly diversified; and the particular set of instincts and the organizing faculty were so adjusted to each other as to cause the resulting organism to be in every respect the best fitted to give full play to the instincts; while these were in like manner the most perfectly adapted to promote the well-being of the organic species.

The successive creation of these organizers resulted in their proceeding, by virtue of the powers conferred on them, to organize a vast multitude of organisms which taken together formed one great and harmonious whole —a perfect system, in which every member was linked to every other by certain bonds of connection, and by the gentlest gradations. Thus, while the organizers were, in the strictest sense of the term, created by the Deity, the organisms were in no case so created. They were elaborated by the organizers, which the Creator employed as living agents for the purpose; so that, when it is affirmed that the Deity made or fabricated the organisms, it is to be understood that He did so—not directly, but through the agency of the organizers which He had created and endowed with the needful powers.

The connection subsisting among all organisms, and which, in the theory of derivation, is regarded as evidence of a common ancestry, is in this theory to be interpreted only as a proof that the organizers have all emanated from one and the same intelligent and designing Mind. A connoisseur in art has no difficulty in tracing the workmanship of any particular artist, however diversified the subjects may be. There is a certain style that runs through them all, indicating to his practised eye that they are embodiments of the conceptions of one and the same imagination. So it is with the organic world. The connections, resemblances, transitions, gradations, are all evidences of an unity of origin certainly; but they prove

that a single Creator, and not a single fabricated organism, was that universal source.

Although the organic system is thus supposed to have been at one time quite perfect in all its parts, without one link in the universal chain having been absent, it subsists in this perfection no longer. A vast number of organizers have utterly perished, and the organisms which they formed lie entombed in the strata. All these extinct species are now missing links in the chain; for when an organizer once becomes extinguished there is no renewal of the creative act to replace the loss. When the whole organisms formed by any specific organizer have once been destroyed, that species of organizer itself ceases to exist. Hence it is that the organic system is now so fragmentary, and that, although it be easy to perceive, by taking a general view, that the whole series of organisms was at one time connected by transitional forms, naturalists have to lament great gaps in the evidence, which even the numerous transitional forms found in the strata are inadequate to supply.

While thus accounting very simply for the mutual relations of all organic beings, the theory of specific creation explains in a much more satisfactory manner, than does that of derivation, the vast and numberless diversities by which they are characterized. More especially does it account for the circumstance that species closely allied in structure may have diverse and contrary instincts and habits. For these result from the diversities of the instincts conferred on the primary organizers; whereas contrariety of instinct, in organisms differing but little in external form and internal structure, can with difficulty be explained on the supposition of derivation from a common ancestor. It is indispensable, however, to the full explanation of hereditary instincts, and especially of those exercised at long intervals of time by very remote poste-

rity, to admit that in every organism of the same species, however varied it may be in form, there is an indefinitely extensible and divisible portion of the first created organizer of that species; so that each successive individual, whatever its form, is only a subdivision of the primary. The necessity for this supposition has already been shown more at large.

It is not at all needful in this theory to suppose that only one organizer for each species was originally created. The same sort of organizer, with the same organizing powers, may have been created in different regions of the earth, which appeared suitable to become the abode of the particular organisms which these organizers were empowered to form. There is thus no difficulty arising out of the circumstance that the same or similar species are found indigenous in very distant localities, the one in the northern and the other in the southern hemisphere, such, for example, as England and New Zealand. It is not necessary to call in the aid of ice, or any similar agency, to account for the transference of the same species from one region to another; for no reason can be assigned why there may not have been several centres of creation for the same species. All that can be said is that the Creator may have seen fit, for some wise purpose, to create the same sort of organizers in various and very distant regions of the globe, and that the organisms which they fashioned thus began to spread from various centres.

The great difficulty involved in this theory is to explain, in a reasonable way, the manner in which the organizers may have at first proceeded to construct their organisms, and more especially to discover the site in which the process was conducted. This difficulty is obvious in the case of the larger animals, and indeed applies to all except perhaps the most rudimentary organisms. In what situation are we to suppose such an animal as a

lion or an elephant to have been formed by slow degrees? Doubtless the organic elements, from which even the largest animals are now elaborated, are of the most simple kind and of microscopic size. But then there are appropriate sites, in which the entire process of development is carried on, with every needful appliance adapted to the purpose. How was this want supplied in the case of the first organisms, which the organizers had to fabricate?

The older naturalists tried to surmount this difficulty, by imagining the first organisms to have been formed instantaneously; but this was only plunging into another difficulty quite as formidable. For the notion, that perfect organisms leapt instantaneously out of the ground or, as Mr. Darwin expresses it, were flashed into existence, is so intrinsically improbable, that it cannot find a harbour in any reflecting mind. Such a procedure would more resemble what we read of in the legends of magic, than anything that we ever observe of the modes of action followed by the Creator. It is only of late years that any reasonable manner of obviating this difficulty has become possible, and even now it must be admitted that this possibility rests only upon mere analogy.

The discovery of nurse-forms is what has thrown most light on this obscure subject; for it has given an indication of the manner in which a form of considerable complexity may have been elaborated by slow degrees, from a very simple original, through a succession of individuals wearing different forms of increasing degrees of complexity, but all belonging to one and the same species.

To illustrate this point, let us take the case of the fern. Whether is it more probable that the fern or its prothallium was formed first in order? The latter being by much the simpler organism, the probability of its having been first formed certainly preponderates. But seeing

the prothallium is at present developed from a germ, which is a still more rudimentary form, the probability is that the first prothallium was also developed from a germ. Now, although it be impossible to understand the manner in which the primary created organizer formed the first germ, yet this was plainly a more simple act than the instantaneous formation of the entire prothallium, while there is little difficulty as respects the site of organization. The germ was probably at first a mere simple microscopic cell, formed in water or moist earth. To form this cell, was accordingly in all likelihood the first effort of the organizer, in the exercise of the powers with which it was endowed by the Creator. The cell, pervaded by the organizer, would then begin to grow—that is, the organizer would organize fresh materials and assimilate them, in the exercise of its conferred powers, and according to prescribed laws. The simple cell would soon become developed into a germ, the germ would in a little longer time become developed into a prothallium, and on this would be formed the sexual sperm and germ elements. These would unite, as they do now, to form the spore, whence the perfect fern directly springs. This course of procedure appears more probable than that the first fern sprang instantaneously out of the ground perfectly formed, and that the prothallium was subsequently prepared as a nurse-form for the next generation.

Turning now to the animal kingdom, let us take the case of the *Medusa aurita*, or red Aurelia. Here the same question may be put—Whether is it more probable that the Aurelia was formed first, or the polyp from whose subdivisions the Aurelia springs? The probability is here, as before, that the more simple organism, the polyp, had the precedence. But the polyp has at present its origin in a minute spheroid of sarcode covered with vibratile cilia, and this being a much smaller and simpler

organism than the polyp must be presumed to have preceded it in the order of time. Now, although we cannot comprehend how the organizer formed this little lump of animated jelly out of the water by slow degrees, we can be at no loss to perceive this to have been a far more simple act than would have been the instantaneous organization of a perfect polyp without the preparatory form. We may therefore reasonably conclude that the first organizer of the Aurelia commenced operations by first forming the little mass of sarcode, and then developing upon it the vibratile cilia; that, having thus secured for itself a vehicle of present and a base for further operations, it began to elaborate a polyp, and to multiply it according to the powers with which it was endowed; that in due time one of the stems of the polyp enlarged, and began to divide into sections, each of which contained a subdivision of the organizer; that these after a while separated one from another, and each, in virtue of the extensible portion of the primary organizer by which it was pervaded, became ultimately developed by metamorphosis into an Aurelia. This appears to be a more probable course than that the Aurelia, a much more complex organism, was formed first and instantaneously, while the first ciliated spheroid of sarcode and the first polyp nurse-form had their origin in this previously existing Aurelia —so reversing the present order of events.

Advancing to a higher grade in the organic scale, let us take the case of the Aphis. The wingless and unsexual form of this insect being less perfect than the winged and sexual, it appears more probable that the former preceded the latter in the order of time than the reverse. But the wingless aphis is at present produced either by internal gemmation from another, resembling itself, or else from an egg deposited by the winged and sexual insect. Now seeing gemmation is an earlier and simpler mode of

reproduction than sexual generation from an egg, it appears more probable that the first wingless aphis was produced by gemmation from a nurse-form still simpler than itself, than from an egg. But, considering how complex is the organization of the wingless aphis, it is not unreasonable to suppose that more than one simpler nurse-form may have preceded it, and that it may have been the last link in a chain of gemmiparous nurses—itself retaining the gemmiparous faculty. The wingless aphis, in its turn, produces a long series of nurse-forms exactly like itself, by far the larger proportion of which perish after having given birth to others by the same mode of reproduction. But the ninth or tenth in succession from the first produces perfect sexual insects, both male and female. This stage attained, fertilized eggs are produced from the conjunction of these males and females, and in the future generation of wingless and unsexual aphides, any earlier nurse-forms that may at first have been requisite are now discontinued as no longer necessary, seeing the wingless aphis emerges perfect from the egg, within which it has passed through all its earlier stages of development, without the aid of more simple preparatory forms.

The same reasoning applies to all other cases in which nurse-forms are still employed. It is always more probable that the preparatory preceded the perfect forms, than that the latter preceded the former. In the instance of those entozoa which pass the earlier stages of their existence in a free state, the probability that the free nurse-forms had the precedence amounts almost to a certainty. It appears not improbable, moreover, that where the perfect form was preceded by a nurse-form which was itself somewhat complex in organization, it may have been in like manner preceded by simpler nurse-forms, which were not repeated in any subsequent generation after the first, by reason of there being other means provided for the reproduction of the species.

But the same line of argument may, by analogy, be also applied to the case of animals undergoing metamorphosis or metagenesis. Take for example the case of a butterfly. It seems more probable that the first caterpillar was formed before the first butterfly of the species, than that these were elaborated in the reverse order. The butterfly is only a more highly developed caterpillar, and we have no reason whatever to fancy that in the case of the first organism of this kind the grub and pupa stages were omitted. But even the caterpillar, when it first emerges from the egg, is perhaps too complex an organism to have been formed without some sort of preparation. This consideration raises a probability that it had its origin in some still more simple form; and in confirmation of this conjecture may be cited the case of the *Ophionurus*, in which such a preparatory form preceding the grub still subsists. Following this analogy, we may imagine the earliest organizer of the butterfly to have begun its operations by forming a ciliated monad, which by growth and development attained a form similar to the preparatory stage in the *Ophionurus*, whence by metamorphosis it passed into a small caterpillar, which was augmented by feeding and growth. This stage having been reached, one of two courses might have been followed: 1st. The grub may have, like that of the *Miastor*, acquired ovarian organs, in which were elaborated eggs, whence were internally hatched other grubs, capable of carrying forward the metamorphosis to its highest stage; so producing perfect male and female butterflies empowered to continue their race. Or, 2ndly. The first grub formed by the organizer may have produced others by external gemmation, in a manner resembling that observed in the Cirrhatula and the Salpæ—these others being capable of carrying on the metamorphosis to perfection. In either view it would be needful to suppose that the first

grub nurse-form, having served its purpose, perished and was never renewed.

This hypothesis appears more probable than that the primary organizer of the butterfly first formed an egg, out of which the first caterpillar was hatched. For an egg is a complex structure, containing both sperm and germ elements, with provision for the first nutrition of the embryo, which passes through several stages of development before it becomes a grub. This last is more highly organized than the Medusa; and if preparatory gemmiparous forms were required in the case of the first Medusa, there is no improbability in the supposition of their having been employed in the case of the first caterpillar, and of its having been produced male and female by gemmation from a nurse-form of its own, specially fabricated for the purpose from some very simple organic element, but which being no longer required has perished for ever.

All animals undergoing metamorphosis or metagenesis might be regarded from a similar point of view. It appears more likely that the Pluteus preceded the Ophiurus, the Zoe the Crab, and the Tadpole the Frog, than that this order was reversed. But analogy raises a probability that the Pluteus, the Zoe, and the Tadpole, may all have required for their first elaboration preparatory forms which may have been as unlike themselves, as they are unlike the perfect forms to which they severally give rise; while in the absence of necessity such preparatory forms may have never been renewed. It is constantly found, that wherever a necessity arises, even when it is one of rare occurrence, there is some natural provision by which it is met; as for example the case of the neuter bees, who nurse one of their number into a queen, to meet the rare emergency of the original queen's death, or the case of the polyp which, when it is beheaded, fabricates a new head, or when it is turned inside out, converts its outer

integument into a digestive organ, and its stomach into a cuticle. Seeing then, that there may have been a necessity, in the case of some of the first perfect organisms, that they should be elaborated by means of preparatory forms, would it be contravening the analogy of nature to suppose that such may have been, in some instances, fabricated merely for that one occasion, and that, the necessity having ceased, they were never thereafter renewed?

But it might, on the other hand, be asked, why have preparatory forms been preserved only in the case of a few species, while, in all other cases, if they have ever existed at all, they have never been renewed from the time of their having been first brought into requisition? To this it may be answered that the nurse-forms still reproduced may subserve some useful purpose in the great scheme of creation, while those that have been discontinued may have been adapted to do no more than to elaborate the more perfect forms by which they have been replaced. Take, for example, the subsisting nurse-forms of the aphides, which are produced in such countless numbers. These not only furnish a prey for the lady-birds and other insects, but even during their life they secrete a sweet juice, which is eagerly sipped by the ants, who tickle them with their antennæ to promote its discharge. So doubtless, the polyp nurse-form of the Aurelia serves some other purpose than that of producing Medusæ by sectional divisions of its stem. It probably affords a delicious morsel to some tiny tenant of the mighty deep, unable to pursue more active prey. On the question of what is useful or otherwise in nature, we are not in a position to judge.

And here the question presents itself: May not the nurse-forms still reproduced, subserve a metaphysical, as well as a physical purpose? May they not be intended

as indicators, to point out the method of the divine procedure, in causing the perfect forms of species to be at the first elaborated from the simplest organic elements, even in the case of the higher animals and plants?

The answer is, such a supposition can never rise higher than a mere conjecture; for, by the very terms of the hypothesis, all certain evidence is excluded. If any such preparatory forms ever existed in the case of the higher animals and plants, they have all perished and have never been renewed, so that their existence can never be demonstrated. Nevertheless, a hypothesis of this kind might, in the absence of a better, be justified by analogy; for if one set of perfect specific types have been elaborated by means of preparatory forms, so might another. At least it is open to fair conjecture, that the mode of procedure in the first elaboration of the perfect specific types, in the case of the higher animals and plants, may have in some manner resembled their present mode of elaboration by means of nurse-forms in the case of the lower organisms. The analogy derives strength from the consideration that even the highest animals in the course of their development, pass through transformations analogous to those exhibited by such lower organisms as undergo external metamorphoses; in whose case the probability is strong that the less perfect preceded the more perfect forms in the order of time, on the occasion of their first formation.

The analogy here is at least quite as strong as that founded on by Mr. Darwin, when he reasons from the accumulation of modifications effected by human agency to a similar accumulation supposed to be effected by natural selection. For he can produce no actual example of the transmutation of a lower into a higher species by such means, any more than an example can be produced of the elaboration of one of the higher animals or plants by means of nurse-forms. The assumption that such pre-

paratory forms have perished, and never been renewed, after having once given origin to the more perfect forms of the species, is not more inadmissible than is Mr. Darwin's assumption that a vast number of transitional forms, necessary to establish his theory of transmutation, have, in like manner, perished, after having subserved their purpose, and left no trace of their existence behind, or his other assumption, that a period, greater than that embraced in the history of the human race, was requisite for natural selection to produce such an accumulation of small modifications, as would suffice to raise a lower into a higher species.

There remains to be considered the objection which Mr. Darwin and his followers urge against any theory of specific creation, arising out of the existence in some species of rudimentary and atrophied or aborted organs and members. These, they argue, can be regarded in no other light than as evidences that those species have descended from ancestors which had those members and organs in perfection, but suffered them to degenerate by disuse. Now, it may be freely admitted that, in some few cases, this may be the true explanation. The blind animals found in dark caverns for example, may not have been originally formed without perfect organs of sight; but through long disuse, the eyes may have become atrophied or inert in their posterity. In other cases, however, the rudimentary parts may be of use, notwithstanding their imperfection. The undeveloped front teeth in the upper jaw of the ruminants may be useful in giving firmness to the gum, although they never make their appearance beyond it, seeing they would be useless in nibbling the grass. But the theory of the development of species through the medium of nurse-forms does not exclude inheritance, as one of the means of explaining the presence of apparently useless members and organs. For

these may have existed usefully in the extinct immediate nurse-form of the species, or in some one of its series of nurse-forms, and may have descended by inheritance to the perfect form, by reason of some correlation of parts. This assumption is quite as admissible as Mr. Darwin's notion, that they have descended to the species by derivation from some extinct very remote ancestor of a totally different species. It may even lay claim to greater probability, seeing that, in the case of animals undergoing metamorphosis, members and organs which are fully developed, and useful in some of the larval forms, are often reduced to mere useless rudiments in the perfect forms.

Again, not a few of these rudimentary members may have been introduced merely for the sake of symmetry, and for preserving that beautiful gradation of structure and correlation of parts, which seem to have resulted from a primary law regulating the organization of the entire system. Could we see the organic world in its integrity, with all the gaps left by extinct species filled up, we should then more clearly discern the perfection of that gradation and correlation, and perceive those rudiments of organs or members to be needful elements in completing that perfection. They may not be necessary in an utilitarian aspect; but they are useful in an artistic point of view. They indicate the unity of idea that existed in the mind of the Great Artist. They are links in a vast chain of constructive modification, by which one structure passes through gentle gradations into another. Now, as these structures themselves are all indications of intelligent design, the gradations must likewise be an element in that design; they are therefore evidences of the oneness of the designer, not of his having made a single organism the root and origin of every modification of structure found throughout the organic kingdoms, nor

of his having left all those modifications to be brought about by the influence of external circumstances, the struggle for existence and select breeding.

Again, to account for the vast varieties of form, development, instinct, and other endowments, which distinguish the creatures that have sprung from the primordial cell, the theory of derivation provides no other explanation than the continuous operation of external influences and select breeding, acting without intentional or special guidance throughout immeasurable periods of time. Whereas the theory of specific creation accounts for all those diversities in a much simpler and more rational manner, by supposing them to have had their origin in the special faculties and powers with which the primary organizer of each species was at first endowed by the Creator.

The only real difficulty involved in the theory of specific creation, is that connected with the site of primary organization, in the case of the higher animals and plants. Out of that difficulty the hypothesis of temporary specific nurse-forms provides a mode of escape, which is at least more reasonable than the clumsy conception of the instantaneous jumping together of the inert atoms into perfect organisms. The circumstance, however, that this hypothesis from its very nature admits of no certain proof, seeing all the nurse-forms which may be imagined to have existed in the case of the higher animals and plants, are supposed to have perished and never to have been renewed, places it in the same category as the hypothesis of Mr. Darwin. Both are mere conjectures founded on analogy. The theory of specific preparatory forms rests on the analogy furnished by the actual existence of such forms in the case of some of the lower organisms. Mr. Darwin's hypothesis of the derivation of every higher from some lower species, is founded on the analogy

furnished by the modifications produced by select breeding as followed by man. This latter analogy, however, labours under an inherent weakness, arising out of the circumstance that none of the modifications produced by human interference have ever raised an organism from a lower to a higher grade in the organic scale.

The conclusion to be drawn from the whole investigation is, that the mode in which organic species had their origin is one of nature's secrets, which man has not yet been able to penetrate. Nor does there appear at present to be any reasonable prospect of his ever being able to do more than throw out conjectures on the subject, more or less plausible.

One great advantage which the theory of specific creation possesses over that of universal organic derivation, is its allowing of the entire separation of the human species from all other animals in their organic origination.

There is, indeed, a total absence of direct evidence tending to show in what precise manner the human organism may have been at first elaborated by slow degrees from inorganic elements: so that conjecture based on analogy is here our only resource. But Mr. Darwin's theory of the derivation of the human organism from one lower in the scale of organization rests on no better foundation, and his reasoning from analogy, when applied to this case, is particularly weak. Disburdened of circumlocution and all extraneous details, his argument takes this shape. Because, by select breeding and the accumulation of small modifications through many generations, men have succeeded in producing from the beautiful and handsome wild rock pigeon, such a monstrosity as the English Pouter, represented at page 137 of vol. i. of Mr. Darwin's work 'On Animals and Plants under Domestication,' therefore it may be concluded, that God—no, not God, but an abstraction called 'natural selection,' acting

without intentional or special guidance, may, by a similar accumulation of small modifications through countless generations, have formed the human species from some other species of an inferior grade in the organic scale. This analogy is not only weak but false. It would have been more accurate to have argued, that, because man had succeeded in degrading the wild rock pigeon into a pouter, natural selection might, by an accumulation of small modifications, have degraded some abnormal, inferior specimen of the human species into a gorilla.

On the other hand, the analogy furnished by nurse-forms among the lower organisms, if not much stronger, is at least not inherently false. For in the majority of cases where nurse-forms occur, the creature, by their means, attains a higher level in the scale of organization; although in some few instances the result is reversed. But if this analogy be not of sufficient strength to enable us to regard it as probable, that in the formation of the human organism the Creator had recourse to nurse-forms in order to its elaboration by slow degrees, it may be held sufficient to establish a probability that the formation of the human organism was not sudden but gradual —that, when it was made in secret, curiously wrought in the lower parts of the earth, the mental eyes of the Creator beheld its rudiments yet being unperfect, and that in the volume of His decrees all of them were written, the days they should be fashioned when there was not one among them. The mode of procedure may have been analogous to that of the formation of the perfect type of a species by means of a succession of nurse-forms. But it is not for us to limit the Creator in His modes of operation. He has not seen fit to explain to us the manner in which the human organism was formed; we can therefore never ascertain how its elaboration was accomplished; we can only form a conjecture based on subsisting processes

observed among the lower organisms. These, while they furnish not a few examples of the elaboration of perfect types through a succession of very dissimilar varieties of imperfect individuals within the limits of the same species, afford not a single instance of the formation of a higher species from a lower by the accumulation of a succession of minute modifications operating without special and intelligent guidance. But with respect to the mode of formation of the first human organism, anything which has been advanced must not be regarded as aught beyond a plausible conjecture, which may be reasonably entertained; while certainty of knowledge is, and most probably ever will remain, utterly beyond our grasp.

PART II.

CHAPTER I.

THE WRITTEN RECORD OF 'THE BEGINNING.'

WHILE it has been deemed advisable to conduct the foregoing investigation upon strictly philosophical principles, and to rest every conclusion upon purely scientific grounds, it may be interesting to some readers to append a subsidiary inquiry into another important question, which has haunted many intelligent minds—Are the views which science unfolds to us with respect to 'The Beginning,' capable of being reasonably reconciled with those deducible from a candid interpretation of the narrative relating to 'The Beginning,' contained in the Hebrew records? Had this inquiry been embraced in the main body of the work, the various points involved would have been too much dispersed, instead of assuming that condensed and definite form in which they are now to be presented.

Before entering on this research, an important preliminary point falls to be examined. It is this: in what sense is the language of the Hebrew narrative to be understood? Is it to be viewed as a popular description, framed in accordance with the notions and prejudices of the people to whom it was addressed? Or is it a strictly correct account, intended to convey a general but accurate account of the manner and order of creation? The

solution of these questions may to some extent depend on that of another, namely, is this description to be regarded as the result of a subjective revelation made to the mind of Moses individually, or is it the substance of an old tradition narrated by him, or by some other ancient Hebrew writer?

There is one peculiarity characterizing the first general account of creation, contained in the first chapter of Genesis, which lends some support to the latter view, namely, the absence from it of the sacred Tetragram, or four-lettered name of the Deity, rendered in the authorised English version either JEHOVAH, or THE LORD.[1] This omission admits of a date's being assigned to that part of the record earlier than the days of Moses, who first introduced the Tetragram as an appellation of the Deity. (See Exod. vi. 3.)

Again, supposing it to have been the divine intention to communicate to mankind some explicit information respecting the procedure followed in the creation of the world, it can hardly be deemed probable that the revelation should have been delayed till the time of Moses. It seems unlikely that the first man and his posterity, for so many generations, should have been left in utter ignorance of their own origin, and that of the world at large.

If carefully examined, the book of Genesis will be seen to be, not a continuous history, but a collection of fragments of different narratives. For example, the first narrative ends with the third verse of the second chapter. The fourth verse commences a separate book, in which the sacred Tetragram begins to be first introduced, and to which, therefore, in its present form, an earlier date than the time of Moses cannot be assigned. The fifth chapter in like manner commences a separate narrative; while another seems to begin at the tenth verse

[1] יהוה

of the eleventh chapter, in which the generations of Shem are given in greater detail than in the preceding book.

While it is thus allowable to regard the first chapter of Genesis, viewed by itself, as being not improbably the substance of a tradition handed down from the first man, the same view cannot, with any likelihood, be taken with respect to the first three verses of the second chapter, which relate to the rest of the seventh day. Apart from this narrative itself, there is no evidence to show that the seventh-day sabbath was known to the patriarchs, or that any commemorative observance of it was ever either enjoined or practised before the exodus. The narrative contained in the sixteenth chapter of Exodus makes it clear that the sabbath was unknown to the Israelites before the fall of manna in the desert: while that the command to observe the sabbath was then first promulgated, is expressly affirmed by both Ezekiel and Nehemiah (Ezek. xx. 12; Neh. ix. 14).

This circumstance, coupled with the reference to the divine rest from the works of creation appended to the fourth commandment as it stands in the book of Exodus, while a reference to the Egyptian bondage is substituted in the book of Deuteronomy, raises a strong probability that the first three verses of the second chapter of Genesis, as well as the remainder of that chapter, were the production either of Moses himself, or of some later writer. Hence, on the supposition of the first chapter's being the substance of a traditional narrative of the events of creation handed down from the first man, it must be presumed that, when it was prefixed to the patriarchal records, either by Moses, or by some later author, or compiler, this statement respecting the divine rest, and the blessing and sanctifying of the seventh day, was added to the original tradition after the promulgation of the fourth commandment.

As regards the character of the terms employed in the description of the work of creation, a careful examination will show the improbability of its having been framed in accordance with popular notions. It seems very inconsistent with such a supposition, that the centralisation of light in the heavenly orbs should have been referred to the fourth creative epoch, and that light should have been represented as having ever emanated from any other source than the sun, moon and stars.

Whatever view be taken with respect to the date of the original narrative, two leading suppositions may be entertained in relation to its general character. It may be regarded either as a mere human speculation, or as the substance of a divine revelation. If it be the former, anything like scientific accuracy in its details cannot be expected. If, on the other hand, it be in its integrity the substance of a divine revelation, then would the improbability be extreme that it should be inaccurate in any important particular, or that its language should have been framed to chime with the popular notions and prejudices of the Hebrew nation. The more probable conclusion would be, that these popular notions, in so far as they were erroneous, arose from misconceptions of the statements of this narrative, and that such mistakes may have been caused, in part at least, by there having occurred during the lapse of ages, changes in the meaning of some of the words employed.

It appears possible, however, to take a view of the narrative intermediate between these two suppositions with respect to its character. The main design of the record is obviously to convey the great truth, that all natural objects, and the human mind itself, owe their origin to an Intelligent First Cause—to an omnipotent and omniscient Being, who existed before that beginning to which the narrative relates. Now it may have been this leading

truth alone that was impressed on the mind of the narrator, seeing it was the only one which was really of essential importance; and it may have been so impressed—not by audible words addressed to the outward ear, but by a conception awakened in the intellect, in that same inexplicable manner in which all original ideas take their rise. As regards the language in which this great truth is embodied, the particular form which the narrative has assumed, the details which it embraces, and the order in which these are arranged, the narrator may have been left to the free exercise of a vivid imagination, swayed by an acute understanding. According to this view, the leading truth alone would be clothed with the certainty due to divine inspiration, and would thus approve itself to every reasonable mind. But the details of the narrative and the order of arrangement might claim no higher degree of probability, than what is due to the conceptions of an enlightened and powerful human intellect; while they would nevertheless be entitled to the same amount of candid consideration. Should it be ultimately found impossible to reconcile those details with the discoveries of science, this view might afford a reasonable alternative.

If the narrative, in its integrity, be the substance of a divine revelation made to the first man, it would most probably be originally handed down in the primitive language spoken by Noah. And here a difficulty arises out of what is related respecting the confusion of tongues; whence it might be inferred that the original language, previously spoken by the whole of the descendants of Noah, was lost in the confusion; so that any record, whether written or traditional, existing prior to that date would have been thenceforth unintelligible. This difficulty, however, might be evaded by a simple hypothesis. The account given of the confusion of tongues does not absolutely exclude the supposition that, while the general

mass of mankind became unintelligible to each other, beyond the sphere of each man's own family, some few, or even one family only, may have retained the primitive tongue, which would thenceforth be understood by them alone. Neither does that narrative prohibit our regarding some old form of the Hebrew language as being the one which was originally spoken by all, but which from that date became confined to the family of Eber and their descendants. Nor is there anything to exclude as unreasonable the supposition, that the dialect retained by this family may have undergone such profound modifications before the narratives acquired their present form, as to render these little more than translations from the primitive tongue. Were this view to be regarded as admissible, it would go far to explain how the original traditions respecting the creation of the world became confined to the descendants of Eber, while they were forgotten by all the rest of mankind.

Were this hypothesis adopted as a basis of argument, it would then become further probable, that all the expressions used in the original narrative respecting the creation, may have been employed in their most primitive sense, and that their meaning may have afterwards undergone various shades of modification from the influence of new associations. It is quite possible, however, in accordance with this view, that the primitive meaning of those terms may be still discoverable from the manner of their original application, and also from their etymological relations.

The question, again, whether this narrative be the substance of a divine revelation, or a mere human speculation, wholly depends on the possibility of reconciling its details with the discoveries of modern science. If such a reconciliation be clearly impossible, then is it equally impossible to prove the narrative to have been divinely inspired

—at least as respects its details. There is no other known mode of proof to which recourse can be had; for in such a case, mere tradition must count for nothing. On the other hand, if it can be shown that the narrative contains statements altogether unlikely to have been made by a mere human theorist, under no other guidance than his own reason and fancy; and if it can be further established, that without violating any philological principles or grammatical rules, the narrative may be so interpreted as to place it in agreement with the discoveries of science —then, in the same degree that this correspondence can be made evident, will the divine authority of the entire narrative be rendered probable.

CHAPTER II.

THE HEAVENS AND THE EARTH.

The Hebrew narrative of creation commences with these memorable words, 'In the beginning God created the Heavens and the Earth.' These two terms 'the heavens and the earth,' in Hebrew the *shamayim* [1] and the *arets*,[2] are to be understood as comprehending the whole material system; for in the sequel, the name *shamayim*,[1] 'heavens,' is applied to all the regions beyond the earth—seeing that in them were placed the heavenly luminaries. It is to be carefully noted, however, that these two names are afterwards applied to distinct *objects*, of whose formation a special account is given. The general statement, that 'God created the heavens and the earth,' does therefore by no means of necessity involve the idea, that the *substance* of which these objects consist was at one time absolutely non-existent, and brought into being by the mere volition of the Deity. The heavens and the earth did not at first exist as distinct objects: and it is subsequently affirmed that they came into existence as such by an exercise of divine power; but of the substance of which the heavens and the earth were formed—that is, of matter in the abstract, nothing whatever is averred.

No light is thrown upon this subject by the verb *bara*[3] here used, and which our translators render 'created.'

[1] שמים [2] ארץ [3] ברא

The notion that this Hebrew verb of necessity involves the idea of making something out of nothing is a mere grammatical figment. Its true meaning is simply 'to cause,' without specifying the manner of causation. Thus in Isaiah xlv. 7, this verb is applied to designate the Deity's causation of darkness and evil—'I cause darkness,' —'I cause evil'—expressions in which the verb cannot possibly imply the absolute creation of substance from nothing. In the causation of darkness and evil, the result flows—not from any direct action of the Deity, but from his withholding his interference or activity. So also in Numbers xvi. 30, the same verb is applied to God's causing the occurrence of an event—namely, the opening of a fissure in the earth, which swallowed up Dathan and Abiram. The narrative affirms that Moses said, 'But if the Eternal create a creation' in reference to the catastrophe which was about to happen. Here the more correct translation would be 'cause an occurrence.'

In the case before us, the verb implies simply that God caused the existence of the *objects*, which were afterwards named the heavens and the earth—the manner of his causing them to exist being afterwards explained more at large; but it is not averred that He formed them in the absence of any pre-existing *substance*. On the contrary, it is affirmed in chap. ii. 4, that the heavens and the earth were created, or caused to exist, by the Lord God's *making* them. 'These are the generations of the heavens and the earth, in the creating of them, in the day the Lord God *made* the earth and the heavens.' In this latter phrase, the verb employed signifies to make or fashion—that is, to operate on an already existing material. Hence the question of the past eternity of matter is left by this narrative in quite as much uncertainty as it has been shown to be left by science.

After the general announcement that the heavens and

the earth, regarded as objects of perception, owe their existence to the Deity, the Hebrew narrative proceeds to describe the first condition of the entire material system, before God began to exert on it his formative power. The heavens (*shamayim*[1]) appear to have been at first confounded with the fluids (*mayim*[2]), from which they were subsequently separated, as afterwards described. They must accordingly be held as embraced under the more general term 'fluids' (*mayim*[2]) till that separation was effected.

Of the earth, again, it is affirmed that it was at first *thohu*[3] and *vohu*.[4] The meaning of these two words is best discovered from the manner in which they are associated with other terms in Isaiah xxxiv. 2. In describing the desolation of a country, the prophet says—'He shall stretch out upon it the measuring line of *thohu*,[3] and the weighing-stones of *vohu*.[4] Hence the former term involves some idea of extent, the latter of weight. They are obviously both negative terms—*thohu*[3] being what the line cannot measure, *vohu*[4] what the weighing-stones cannot weigh.[5] It is, moreover, curious that these two nouns are almost always associated together, as if there were some necessary connection between them—as if that which is *thohu* must of necessity be also *vohu*. According to this view, then, the first condition of the earth, as here described, was that of a material without definite limits and without weight. The nouns being used as adjectives; the best translation is perhaps—'the earth was vast and void.'

This description points strongly to that condition in which matter would subsist, were its constituent ultimates destitute of all properties save those inseparable from their mere existence — namely, size, form, and

[1] שמים [2] מים [3] תהו [4] בהו [5] See note S.

impenetrability, having no mutual relations, each ultimate being absolutely indifferent to every other. So far, then, this description tends to confirm the idea of matter's having at one time existed in that state—a condition which, as it does not of necessity involve any idea of design or intention, is the only one consistent with the supposition of the past eternity of matter. At the same time, their having at first existed in this state of absolute mutual indifference, would not prove the material ultimates to have been eternal. For the Deity might have primarily created them in that condition, and afterwards endowed them with their various relative properties by successive acts of volition.

Some have fancied this description to apply to the earth—not in its pristine condition, but in a state into which it had fallen after having been formed, and even after it had been previously clothed with vegetation, and inhabited by animals; but this interpretation is inadmissible. For it appears from a subsequent statement, that the earth was either blended with the fluids (*mayim*) or covered by them—indeed that the *object*, to which the name 'earth' is applied, did not receive from its Framer that distinctive appellation until a subsequent stage in the formative process. Now this description cannot apply to an already formed earth merely flooded with water. Had that been the real condition of the globe at this epoch, it would, in a history professing to tell the simple truth, have been described in terms similar to those applied to the earth when covêred by Noah's flood, instead of by those two terms which are of such peculiar import. Moreover, it must be borne in mind, that the structure of the earth indicates it to have been formed—not all at once, but by successive stages; so that there must have been in the remote past, a period when the terms *thohu* and *vohu*, vast and void, would be accurately

descriptive of its condition, before it had received shape or dimensions appropriate to itself. It is accordingly not allowable to refer this description to any other period than to that beginning, to which it is the obvious intention of the narrator that it should apply.

The next averment of the record is—'And there was darkness on the face of the deep.' The word rendered 'darkness' is in the Hebrew *hoshek*,[1] which comes from a verbal root of the same form,[1] signifying either 'to darken' (when it is pronounced *hâshak*[1]), or 'to restrain, withhold, or refrain' (when it is pronounced *hâsak*[1]). It is used in the latter sense in Gen. xxxix. 9: 'Neither hath he kept back (*hâsak*[1]) anything from me.' Also in Job xxi. 30: 'The wicked is reserved (*yahâsek*[2]) unto the day of destruction.' This verb thus involves the idea of refraining from action, or restraining action; so that the idea of repose or stillness is associated with that of darkness in the derived noun. Indeed these two ideas are inseparable. For light being simply motion, there could not be stillness unless there were also darkness, although there might be motion without light. The double idea of darkness and stillness, however, is confirmatory of the view, that the original condition of the material ultimates, as here described, was one of absolute neutral indifference and repose.

The word rendered 'the deep' is in the Hebrew *thehom*[3]; but in the original the definite article is absent. Diverse opinions have been entertained with respect to the origin of this word; but the most reasonable seems to be, that it is related to *thohu*, which when used as an adjective means 'vast.'[4] According to this

[1] חשך [2] יחשך [3] תהום.

[4] See note T.

view, the English word 'immensity' would be the nearest representation of '*thehom.*' 'And there was darkness (involving stillness) on the face (or aspect) of immensity.'

This ends the description of the first condition of the universe, before the Deity began to exert on it his formative power.

CHAPTER III.

THE FIRST CREATIVE EPOCH.

The next clause of the narrative begins the description of the various processes, by which the raw material previously described was wrought into the forms which it afterwards assumed. The first step was to terminate the stillness and darkness. For this purpose it is averred 'the spirit of God *mirahefeth*[1] upon the face (or aspect) of the *mayim*.'[2] This word *mirahefeth*, commentators are agreed, means the producing of a tremulous or vibratory motion. God then by his spirit (or vital energy) acting on the *mayim*, caused them to assume a vibratory motion, saying 'Be light,' and it was light. Thus these two clauses, taken together, show that the vibratory motion of the *mayim* produced light. The *mayim* here mentioned, as already indicated, embraced both the *shamayim*[3] and the *arets*[4]—the heavens and the earth, neither of which had been yet separated from them. In short the *mayim* were the materials of *thehom*[5] the vast. Now, while the word *mayim* is generally used specifically to designate 'waters,' yet it is occasionally applied in the Hebrew Scriptures to other fluids, so that it is plainly capable of a generic extension.[6] From the manner in which it is here used, and from the sequel, it ought in this passage to be understood in its generic sense, and to be rendered by our correspond-

[1] מרחפת [2] מים [3] שמים [4] ארץ [5] תהום

[6] See note U.

ing generic term 'fluids.' What may be gathered then from this first part of the description is, that *thehom*,[1] immensity, out of which the *shamayim*,[2] the *yammim*,[3] and the *arets*,[4] the heavens, the seas, and the earth, were subsequently formed, was occupied by *mayim*[5] fluids, which had neither limits nor weight, and which, by having a vibratory motion imparted to them, produced light.[6]

Had the author of this narrative been perfectly acquainted with the undulatory theory of light, he could not have employed language more in consonance with its principles, than are these words: 'The spirit of God induced a vibratory motion on the aspect of the fluids, and God said "be light," and it was light.'[7]

These words indicate a marked connection between the vibratory motion and the production of light. They lead us to understand the primæval light to have been originated by the direct action of the Divine energy which caused undulations in the Ether, without their being propagated from any particular sources, as they afterwards came to be, when the heavenly orbs were constituted centres of illumination.

If the foregoing interpretations be deemed reasonable, it will be perceived that the account given in the Hebrew narrative, both of the first condition of matter and of the events of the first creative epoch, agree very fairly with the conclusions previously deduced from purely physical considerations. The narrative describes the universe as having at first consisted of indefinite *mayim* diffused through an infinite *thehom*, constituting together an

[1] תהום [2] שמים [3] ימים [4] ארץ [5] מים

[6] See note V.

[7] That this mode of rendering the passage is legitimate may be perceived by a simple inspection of the original, and by comparing the words 'and it was light,' with the words 'and it was so' which conclude the 7th verse. The form of expression is in both passages the same.

infinite assemblage of ultimates absolutely indifferent to each other, weightless and formless. It declares the Deity to have begun to exert his energy on this medium by exciting in it a vibratory motion; and this involves the idea of his having conferred on an indefinite portion of the material ultimates certain properties of mutual repulsion regulated by determinate laws, in virtue of which they became capable of assuming the vibratory motion, and transmitting it from point to point—so producing the undulatory phenomena constituting light. There seems to be further involved the idea that, from the infinitude of material ultimates thus endowed with repulsion, a definite portion was reserved to be afterwards endowed with attraction, so as to be capable of being accumulated into masses possessing weight, and constituting the earth and the heavenly bodies. Until this property of attraction was conferred, these reserved ultimates would appear to have retained their original indifference to each other. It is left open to conjecture, however, whether the impulse of the motive energy thus put forth by the Creator was at first applied directly to the ultimates of the Ether itself, or to the indifferent ultimates mingled with them, which by communicating their motion to the ethereal ultimates propagated luminous undulations through the Ether, each indifferent ultimate being thus a centre of motion. The phrase that God excited the motion on the *mayim* rather than on *thehom* favours the latter conclusion.

The word *or*,[1] moreover, employed in the passage under consideration, and by our translators rendered 'light,' is also occasionally used to denote 'flame;' and it is accordingly fair to conclude that the idea of heat, as well as of light, may be here involved.[2] Indeed, this could

[1] אור

[2] See note W.

not fail to be the case, if, as above supposed, there were indifferent ultimates intimately mingled with the repulsive ultimates constituting the luminiferous Ether. For heat is simply a vibratory motion of the non-repulsive ultimates, as light is a similar motion of the repulsive. Hence if these two sorts of ultimates were at first intimately blended, they would partake of each other's motions, and it would be indifferent with which set the motion commenced. In either view we must assign to the non-repulsive ultimates a vibratory motion of their own, which would in them constitute a certain amount of temperature. This they might possess before they had acquired any relative properties towards each other; but it would involve the idea of a repulsion subsisting between them and the ultimates of the Ether, otherwise these two could not set each other in motion.

All these inferences may be drawn with equal fairness from the Hebrew narrative and from the discoveries of modern science.

The record next proceeds to narrate that God, seeing the light to be good, fitted to serve the ends He had in view, divided or distinguished it from the darkness, and gave distinct names to the two periods in the history of creation which had now emerged. The period, during which the universe had lain in quiescent darkness, He called *layelah*,[1] and the period, beginning with the vibratory motion and its consequent light, He called *yom*.[2] In this, their original application, these two words had probably a somewhat different meaning from what they afterwards assumed, when man became an inhabitant of the earth. It was natural that, after that epoch, these terms *yom*[2] and *layelah*[1] should be employed by mankind to designate the alternations of light and darkness, produced

[1] לילה [2] יום

by the change of their own position on earth with respect to the central luminary, and that they should thus come to signify a natural day and night. In their original application, however, they could have hardly had precisely this same meaning. For, according to the narrative, there were as yet no central luminaries, neither had the mass of the earth been yet separated from *thehom*[1] the vast. Moreover, as the description throughout bears reference to the universal system, and not to any particular locality on the face of the earth, these terms could not, even after the establishment of central luminaries and planetary revolutions, have their ultimate application; because, with reference to the globe as a whole, there is neither night nor day. The meaning then of the terms *yom*[2] and *layelah*,[3] as originally applied, must have been merely periods of light and darkness; the indefinite dark period, which preceded the existence of light, being called *layelah*;[3] the light period which followed being called *yom*.[2]

Now it is remarkable, that there is no mention of any recurrence of a *layelah*,[3] or period of darkness, during the whole course of the subsequent formative processes. The light, once brought into the field, maintained its ground; and in confirmation of this view we find, that the period during which God made or fashioned the *shamayim*[4] and the *arets*,[5] is afterwards affirmed to have been a continuous *yom*[2] or period of light. In chapter ii. v. 4, it is said, 'These are the generations of the heavens and the earth, when they were created, in the *yom*[2] that God the Eternal made the earth and the heavens.' The general material, out of which the heavens and the earth were framed, either primarily existed, or was created during a *layelah*,[3] or period of darkness; but God fashioned them

[1] תהום [2] יום [3] לילה [4] שמים [5] ארץ

out of that material in a *yom*[1] or period of light. This is one out of several other proofs, that the term *yom*,[1] as used in this narrative, does not mean a day in the ordinary acceptation; but that it has throughout the more simple and primitive meaning of a period of light. It is also a proof that there was no intervening *layelah*,[2] or period of universal darkness, during the time that the work of creation was continued, but that light prevailed throughout the whole series of operations.

How then is this statement to be reconciled with the mention of six successive *yomim*?[3] The explanation arises out of a consideration of what formed the basis of separation into those six. This basis was not a *layelah*,[2] or period of darkness; but each *yom*[1] was characterized by an *erev*[4] and a *voquer*.[5] To find out the meaning of these two terms in this their first application, recourse must be had to their etymology. The former is derived from the verb *ârav*,[4] to mingle, confuse, or conceal. The latter is derived from the verb *biquar*,[5] to search out, discover, survey, disclose or develop. The primitive meaning of *erev*,[4] therefore, is 'mingling' or 'concealment.'[6] That of *voquer*[5] is 'a searching out,' 'disclosure,' or 'development.'

These terms came to be applied to the evening and the morning; because the former is the time when lights and shadows become mingled and objects concealed, while the latter is the time when objects become searched out, as it were, and disclosed to view. In this their original application, however, these terms could not denote the periods of sunset and sunrise; because at this epoch, there was, according to the narrative, neither the one nor the other. From the particular manner in which they are here used, these words appear to be

[1] יום [2] לילה [3] יומים [4] ערב [5] בקר
[6] See note X.

descriptive of events, by which the successive *yomim*[1] were distinguished; for they are introduced in a peculiar way, rather as characterizing than as composing the *yom*.[2] It is not said, 'and an *erev*[3] and a *voquer*[4] were one *yom*;'[2] but it is said—'and there was an *erev* and there was a *voquer* one *yom*.' Rendered literally and etymologically, it is—'And there was a mingling (or concealment) and there was a disclosure (or development) one light period.'

There were thus two events characterizing this *yom*;[2] the first was the creation, in a state of universal commixture, of the whole materials out of which the worlds were formed; or, supposing the mere substance to have always existed, there was at least the endowment of the already existing material ultimates with certain properties regulated by determinate laws, invented by an intelligent mind; a definite portion, however, being excepted, but left intermingled with the rest. The second was the vibratory motion, by which not only was the light produced, but the difference disclosed between the two kinds of matter composing the fluid *thehom*;[5] the one kind being capable by its vibrations of producing light; the other being by its inertia, or power of resisting motion, afterwards acquired, capable of so interrupting the vibrations of the other sort, as to cause darkness. These two kinds of matter were not indeed as yet separated from each other, as respects space; but the luminous vibrations rendered manifest the difference between them. There were thus first a condition of things, in which that difference was concealed: and this was followed by a condition of things in which that difference was developed. The distinction in the Divine Mind between the two sets of ultimates in their relation to light, may also be implied in the statement that God distinguished the light from the darkness. It will afterwards be seen that each succeeding *yom*[2] was characterized by similar events.

[1] יומים [2] יום [3] ערב [4] בקר [5] תהום

Several expositors, in treating of this passage, have conjectured that the light of the first day was that of the sun, but that its emanation from that luminary could not have been perceived by the eye of a spectator viewing it from the earth. They imagine to themselves a mass of dense vapours, so dense as entirely to conceal the disc of the sun, yet not thick enough to prevent a portion of his light from reaching the earth's surface. Some of these commentators will not even allow that light now for the first time emanated from the sun. They suppose him to have been shining from of old, from an indefinite period of the past, but that up to this time the vapours surrounding the earth were so very dense that his rays could not penetrate them at all; and hence the darkness described in the second verse. Consequently, when God pronounced the command 'Be light,' He did not, according to this view, then for the first time originate light; He merely thinned the vapours which prevented its penetration. Yet, with marvellous inconsistency, some of these same commentators interpret the subsequent description of the work of the second day as meaning the formation of the earth's atmosphere. Now, it is well known to chemists that the existence of the atmosphere is indispensable to the subsistence of dense vapours. Watery vapour, if diffused in a void, is quite transparent and colourless, and would not absorb more light than atmospheric air. It is only when watery vapour assumes the vesicular form, by its diffusion through cool atmospherical air, that it becomes dark and forms clouds and mists. Nor is there any other known vapour which, in the absence of the atmosphere, could have surrounded a water-covered globe so as to obscure from it the solar light. Nitrous acid gas, which has a greater power of absorbing light than any other vapour, could not subsist for any length of time over water, by which it is greedily absorbed. For

the same reason, the coloured vapours of iodine, chlorine or bromine could not have thus invested the globe. The existence of air is in like manner necessary to the formation of smoke. There is thus no known vapour which, prior to the existence of the atmosphere, could have enveloped the globe in such a manner as to exclude from it the light of the sun, had such previously existed. This hypothesis of vapours shutting out the solar light in the absence of the atmosphere is therefore untenable.

Few will be disposed to deny that there must have been a period when the sun did not shine. If then his shining must have had a beginning, it is surely gratuitous to transfer that commencement from the period assigned to it by the narrative, (namely the fourth day), to this the first day, in the absence of all need for such a transference, more especially when it entails the necessity of calling in the aid of some unknown species of dense vapours surrounding a water-covered globe before the existence of the atmosphere. The consideration of this point, however, will be resumed with more advantage hereafter.

CHAPTER IV.

THE SECOND CREATIVE EPOCH.

The next process described in the Hebrew narrative is the extrication of the *shamayim*[1] from their combination with the *mayim*,[2] and the separation of the latter into two different portions.

The description is peculiar—'And God said, "Let there be a *raquia*[3] in the midst of the *mayim*,[2] and let it be a dividing between *mayim*[2] into *mayim*."[2] And God made the *raquia*[3] and divided the *mayim*[2] which were under the *raquia*[3] from the *mayim*[2] which were above the *raquia*;[3] and it was so; and God called the *raquia*[3] *shamayim*.'[1] Now this word *raquia*[3] comes from the verb *raqua*,[4] to rack or stretch, and therefore means a stretching out, or anything stretched out—an expanse, a reach. It was not, however, mere space; for it was occupied by, or consisted of, a something—a kind of *mayim*,[2] which were called *shamayim*.[1] Various opinions have been given by etymologists in regard to the root which enters into combination with *mayim*[2] to form this compound word *shamayim*[1]; but one of the best supported makes it to be *esh*[5] 'fire.'[6]

According to this etymology, the primary meaning of the word *shamayim*[1] would be 'fire-fluids'; nor is it easy to conceive of any more appropriate name for the fluids

[1] שמים [2] מים [3] רקיע [4] רקע [5] אש

[6] See note Y.

which occupy the vast expanse, and compose that elastic medium whose vibrations constitute light and cause heat, and which philosophers have termed the ether. There was thus effected a separation between the two sorts of *mayim*[1] or fluids which composed the original *thehom.*[2] Those capable of the vibratory motions which constitute light were chiefly placed in the expanse and called 'fire-fluids'; while the rest of the *mayim*[1] were by means of the expanse separated into distinct portions, to be applied to other purposes. Reasons have been already assigned for believing the luminiferous ether to consist of two fluids intimately mingled, mechanically alike but chemically different, having as regards their repulsive energy different relations to diverse sorts of chemical ultimates. Supposing this view to be correct, it is remarkable to notice the plural form 'fire-fluids' bestowed on the expanse.

It is curious that the Greeks rendered the Hebrew word *raquia*,[3] or expanse, by the term *stereôma*,[4] or firmament—a word implying fixity of position or place. Now it is a property of the ether, as conceived of by modern philosophers, that each ultimate, or centre of elasticity, of which it is composed, has a fixed position in space, from which it never departs, except to the minute distance involved in an undulation, and to which it immediately returns when the agitating force ceases to act. Thus the ether, while it is an expanse, is also a firmament, every particle of which retains a normal position in space; whereas all ponderable matter is continually changing its position—no one ultimate of it ever remaining in the same absolute portion of space for two consecutive moments of time. This singular coincidence might almost lead one to imagine that the ether of modern philosophers may be only a rediscovery of what may have been known to some of the wiser among the ancients.

[1] מים [2] תהום [3] רקיע [4] στερέωμα.

From the manner in which the separation of the *mayim*[1] or fluids into different portions is described, it would appear to have been effected by the detachment of the portion belonging to our globe from the rest. God made the expanse, and by means of it separated the fluids under or on the mundane side of the expanse from the fluids above or on the ultra-mundane side of the expanse. It may be hence inferred that the former were a small detachment from the greater mass which were beyond, and kept apart by the fire-fluids.

That by these *mayim*[1] above or beyond the fire-fluids the Hebrew writers understood, not the atmospheric waters, but something altogether out of the sphere of the earth, appears pretty evident from the tenor of the 148th Psalm. The Psalmist there invokes certain objects to praise God from the earth, and certain others to praise him from the heavens, or fire-fluids. Among the former he classes the atmospheric waters; but among the latter he classes the *mayim*[1] above or beyond the *shamayim*.[2] It may hence be inferred that by the latter he understood, not the atmospheric waters, nor anything belonging to this earth, but the fluids of other worlds. Now, if it be remembered that the mundane portion of the *mayim*[1] embraced the whole materials of which our globe was composed, and which had not yet been separated one from another, it is reasonable to suppose the ultra-mundane *mayim*[1] to have been similarly constituted, and to have been in like manner the mixed materials out of which all the ultra-mundane bodies were formed.

According to this view, the description here given applies to the formation of the vast ethereal expanse, and to the separation, by its means, of the other species of matter into numerous masses, to form planets, suns, and stars. Thus the second *yom* or light-period, like its pre-

[1] מים [2] שמים

cursor, was characterised by a condition of things in which certain materials or objects were mingled together and concealed ; and secondly, by a separation of those materials or objects, resulting in their disclosure or development. Thus there was a mingling or concealment, and there was a disclosure or development *yom* second.

Up to this point, then, there is no discrepancy between the discoveries of modern science and the averments of the Hebrew narrative rightly understood, but, on the contrary, a rather remarkable amount of agreement.

CHAPTER V.

THE THIRD CREATIVE EPOCH.

By the expanse, then, which was formed during the second creative epoch, is to be understood, not simply the earth's atmosphere, but the whole of that boundless reach occupied by the ether or fire-fluids ; for we are afterwards informed that it was in this region that the sun, moon, and stars were placed. The earth's atmosphere, however, is also comprehended in it ; because, although in the atmosphere the ether exists intermingled with gravitating matter, yet the former greatly predominates, and is still capable of freely receiving and transmitting luminous waves. The formation of this open space might, according to this view, have been caused by the force of gravity's being, now for the first time, imparted to those reserved ultimates, which had been hitherto blended with the repulsive ultimates, constituting the ether, and by their retiring and assembling round their respective centres of gravity. Our globe is, accordingly, to be regarded as one of the masses thus formed ; while all the other *mayim* or fluids beyond the expanse went to form the countless other masses distributed throughout the boundless realms of ether.

It has been shown in the earlier part of this work that, when it was first formed into a separate mass by the force of gravity, our globe was probably in a molten condition, from which it cooled by slow degrees, until it became

encrusted all over with a solid stratum, covered externally by an ocean and an atmosphere; as also that the waters constituting the ocean and the gases constituting the atmosphere alike issued from the interior, through the fissured crust, the water being at first in the condition of vapour, and in union with the atmospherical gases, whence it distilled by cooling into the liquid state.

That our globe was thus at one time entirely covered by water is a fair inference, both from general physical considerations and from geological phenomena. At least, it would be hard to adduce any evidence to prove conclusively that the earth was never at any time in its past history wholly submerged under water. The same inference follows from the statement of the Hebrew record with respect to the gathering together of the waters and the appearance of the dry land.

The terms used in narrating this event indicate that during the previous epoch a large proportion of the materials of the globe had become consolidated, and were at the beginning of the third epoch merely covered by the fluids; for the land is spoken of as already existing, ready to appear on the retirement of the waters. 'Let the fluids (*mayim*) under the fire-fluids, or heavens (*shamayim*), be gathered into one place, and let the dry land appear.' The land is thus mentioned as a thing already formed; so that the oldest portions of the rock formations would appear to have been consolidated during the second epoch. This gathering of the fluids seems, from the appearances presented by those older rocks, to have been accomplished chiefly by volcanic or other subterranean agency, which operated by elevating certain portions of the consolidated crust and depressing others, so producing numerous heights and hollows, some of the latter being of large dimensions, into which the waters were collected.

The narrative next proceeds to describe the manner in

which the dry land was covered with vegetation; but this part of the description will be more advantageously considered in the sequel.

The epoch during which the dry land was thus separated from the fluids and clothed with vegetation was probably of vast duration. To this particular period reference seems to be again made in the second chapter, where it is affirmed that, when the earth was first covered with vegetation, and before there was a man to till the ground, the soil was fertilised by means of a vapour, which ascended from the earth and watered the whole face of the ground; for it had not rained upon the earth. The time here mentioned can indeed be hardly any other than the third creative epoch, which is thus indicated to have been something very different from a mere ordinary day. It is moreover worthy of remark, that the state of things here described was precisely such as might have been expected to subsist before the light and heat became—according to the narrative—centralised in the sun; for that luminary is the proximate cause of rain, wind, and most other meteorological phenomena. Thus the absence of rain indicates the absence of a central source of light and heat; while the circumstance of a vapour's ascending and watering the entire surface of the soil indicates an uniform distribution of temperature over the whole face of the globe. In short, this was merely the phenomenon of dew extending constantly and continuously over the whole dry land.

It has been pointed out that these vapours probably issued from the interior mass of the earth, during the progress of its cooling, and while the temperature near the surface was still high. Though a large quantity had already risen, and become condensed into water, and had also been gathered into one place to constitute the seas, yet there would seem to have been continually issuing from

the fissures of the earth fresh supplies, which became diffused through the atmosphere, whence they were separated in the form of heavy dews, partly by slow cooling, and partly by the action of the vegetation. This action, it is well known, contributes largely to the formation of dew. When the leaves of plants are exposed to a clear sky, they lose heat rapidly by radiation, so that they present to the air, when impregnated with moisture, a cold surface, which, acting as a condenser, causes the moisture to become deposited in dew-drops on the leaves. Now, as there is required, for the development of this phenomenon, a perfectly clear and cloudless sky, it could not exist over the whole dry land at once, unless the temperature were nearly uniform throughout, a condition which could have subsisted only before light and heat became centralised in the sun. It will be particularly noted that the vapour is said to have gone up, not from the seas, but from the earth, thus enhancing the probability that it issued from fissures, and was caused by the high temperature then still prevailing at a short distance from the surface of the ground.

That there was such an epoch in the earth's history as that here indicated is rendered probable by the nature of the fossil remains of the primæval vegetation, the characters of which, in the opinion of the most eminent botanists, indicate, as already mentioned, the prevalence for a long period of an uniform moist climate of equally warm temperature over the entire globe, the fossil vegetation being such as thrives best in a reeking soil; while it was in a reeking soil that the Hebrew narrative affirms the earliest vegetation of the globe to have flourished.

If the description given in the second chapter of the Hebrew narrative concerning the primæval mode of watering the earth apply to the third creative epoch, or even to all those preceding the introduction of man upon

the earth, it seems very unlikely that, had these epochs been mere terrestrial days, so particular a description should have been given of a state of matters which endured for so short a time. But if this third epoch was not a mere terrestrial day, there can be no reason for holding any of the others to have been such. We have thus an additional proof, derived from the record itself, that these were not mere days of four-and-twenty hours each, but periods of indefinite length, and probably of immense duration.

The third *yom* was, like the two preceding, characterised by an *erev* and a *voquer*—a concealment or commingling, and a development or disclosure. For there was, first, the condition of things when the dry land was concealed by the fluids; then there was the separation of those two, resulting in the disclosure of the dry land, and followed by the development of the vegetable world.

CHAPTER VI.

THE FOURTH CREATIVE EPOCH.

The Hebrew narrative having explained the purposes to which the fluids (*mayim*[1]) under the expanse were applied, next intimates what became of those above or beyond the expanse. Up to this period, light had, according to this account, been diffused throughout the whole, or at least a large portion of the space occupied by the fire-fluids (*shamayim*[2]), which had been thrown into a state of universal vibration, and maintained in that condition by a direct exercise of the living energy of the Divine Spirit. This arrangement was now to be changed, and there were to be established numerous centres of vibration, which should be the means of dispersing luminous waves in every direction throughout the regions of immensity.

From the manner in which the establishment of these sources of light is here narrated, it may be fairly inferred that the masses of the heavenly orbs had been formed during a preceding epoch—most probably at the same time with the mass of the earth; for it is merely their property of shedding light that is here mentioned as having been now for the first time conferred: 'Let there be luminaries (*mioroth*[3]) in the expanse of the fire-fluids (*shamayim*[2]).' The general and indefinite nature of this expression indicates that the luminaries were to be

[1] מים [2] שמים [3] מארת

numerous—not merely the conspicuous pair afterwards particularly specified, but the whole system of luminous centres throughout the universe. This conclusion follows of necessity from what was previously stated regarding the universal diffusion of light, which had up to this time prevailed, and it is confirmed by the subsequent mention of the lighting up of the stars as belonging to this epoch.

As only a portion, however, of the countless masses distributed throughout space were constituted centres of luminous vibration, these were to be rendered subservient to the transmission of light to the non-luminous bodies, among which is our earth, and to become the means of causing an alternation of light and darkness on the various parts of their surfaces. As respects the earth, they were to distinguish the *yom*[1] from the *layelah*[2]—the period of light from the period of darkness—and to be to its inhabitants the means of marking times and seasons, days and years. 'And God made two great luminaries (the greater luminary for ruling the day, and the lesser luminary for ruling the night); also the stars. And He established them in the expanse of the fire-fluids, to illuminate the earth'—in common with all the non-luminous bodies throughout the universe. The clause stating that the greater luminary was for ruling the day, and the lesser for ruling the night, is parenthetical, and the verb 'made' governs the noun 'stars,' as well as 'the two great luminaries'— the nouns being coupled together by the particle *êth*[3] in a manner peculiar to the Hebrew tongue. There is, therefore, no ground for supposing the stars to be here mentioned merely in an overly way, to show that God made them, but to have been in reality constituted centres of illumination long before our own

[1] יום [2] לילה [3] את

sun. Let it be observed, however, that it is not the original formation of these heavenly orbs, or their first separation into distinct masses, that is here described. That appears to have been previously accomplished. Indeed, so nicely balanced and adjusted are the forces which regulate the mutual relations of the heavenly bodies, and by which the permanent stability of the universe is secured, as to afford evidence that the whole of the separate masses existing in space were most probably formed at one and the same time. In this part of the narrative nothing further is affirmed than the fact that a portion of the heavenly orbs were at this epoch, and for the first time, constituted centres of illumination.

With respect to the moon, it is mentioned as a source of light merely with reference to the earth, and as a great time-piece to mark by its changes of aspect and position the times and the seasons. It is remarkable that astronomical discovery has tended only to confirm the idea that these are the chief purposes which the moon is designed to subserve.

The statements of the Hebrew narrative, regarding the first illumination of the sun, moon, and stars, when viewed in connection with the discussions contained in the previous part of this work, relative to the nature and probable sources of their light and heat, will be found not difficult of reconciliation with the discoveries of science.

The averments of the narrative respecting the first origin of light have been shown to tally in a remarkable manner with the undulatory theory. Equally with it, they teach us to regard the primary cause of light, not as concentrated in the sun and stars, but as a fluid medium diffused throughout all space—the heavenly luminaries being merely centres of motive energy, by which this universally diffused medium is kept in a state of continual vibration. The narrative more especially

points to this conclusion by averring that, before these centres of force were constituted, those vibrations were excited and maintained throughout the universally diffused fluids, or at least a portion of them, by a special exercise of the Divine energy.

Indeed, the circumstance of its affirming that light existed before the sun was made a luminary is one of the strongest grounds upon which the claims of this narrative to be regarded as true history can be based. For it seems in a high degree improbable that in any mere speculation such an order of events should have been even imagined.

This consideration shows how great is the misapprehension of those who, unable to understand how light could have existed before it began to emanate from the sun, have been fain to fancy the light of the first day to have been merely solar light partially obscured by dense vapours enveloping the earth. This hypothesis involves a degradation of the description of the work of the fourth epoch which is quite inadmissible. It would compel us to suppose the Creator to have done nothing in the course of that epoch, save to blow away a dense and continuous canopy of clouds, which had previously enshrouded the clear sky, and thus to have merely disclosed to earthly eyes about to be formed the already illuminated discs of the sun, moon, and stars. But had such been the real nature of the transaction, a truthful narrative would surely have described the facts as they occurred, and not in the manner in which they are here presented. That the work of the fourth epoch was the first constituting of the sun and stars centres of luminous vibration is the only idea that will satisfy the description consistently with the other statements in the previous part of the narrative.

There remains for consideration the question, Is the Hebrew record of these events, and the order in which it

places them, reconcilable with the theories of the constitution of the sun which have been brought under review in the previous part of this work?

According to the meteoric hypothesis, the sun must have been first a nucleus of some considerable size, into which meteors have been successively falling during a long succession of bygone ages. But the original size of the nucleus, and the period when the meteors first began to fall into it, are points left quite open to conjecture. One thing this theory assumes as certain, that there must have been an epoch when the sun first began to shine upon the earth, an epoch most probably of very remote antiquity. The Hebrew narrative is nowise inconsistent with this conclusion, provided we assign to the *yom* an indefinite duration. But this requirement has been shown to be necessary to any reasonable scheme of reconciliation between the statements of the narrative and the discoveries of science. The meteoric theory, on the other hand, offers no hindrance to our supposing that, before the meteors began to fall into the sun, and furnish it with the requisite amount of motive energ to supply its light and heat, the earth may have derived these from some other source. The probability of its having done so rests entirely on geological evidence, and is not affected by the meteoric theory.

Indeed, the question of reconciliation rests much less between the meteoric hypothesis and the Hebrew narrative, than between the former and the phenomena of geology. The deposition of sedimentary strata may be reasonably regarded as the earliest evidence of solar action on this globe. Now, the immense mass of those deposits indicates that millions of years must have been required for their accumulation, how many millions it is impossible to say. The meteoric theory provides sunshine equal to that now subsisting for between seven and eight millions

of bygone years; but the Hebrew narrative sets no limit to the period, provided we assign to the *yom* an indefinite duration.

It is rather more difficult to reconcile the statements of the Hebrew narrative with the theory of the sun's being a cooling mass, which has been gradually giving off light and heat, for an unknown period of time, without any accession of temperature from without, or renovation of motive energy from within. The most feasible method of reconciliation is to suppose that, when the earth was formed into a separate individual orb, the substance now composing the sun still continued in the nebular condition, forming a luminous medium which filled nearly all the space within the limits of the earth's orbit. We must further suppose this condition to have subsisted until the end of the third creative epoch, after the earth had acquired its primitive vegetation. But when the fourth epoch commenced, we must imagine the nebulous matter to have gradually condensed into a central mass, so as to form the solar orb, which, according to this view, must have been of greater size than it is now. It seems needful also to suppose that, during the progress of this condensation, our moon and the two inferior planets were formed out of the nebulous mass. With respect to the fixed stars, it may be supposed that they were in like manner formed by the condensation of nebulous matter during the same epoch. The period being assumed to have been of indefinite duration, the process of condensation may have taken place by very slow degrees.

The language of the narrative would easily accommodate itself to this view; for the primæval light would be that of the nebulous matter, before it became condensed into a sun; while the centralisation of light in the sun and stars, effected during the fourth epoch, would be accounted for by the condensation of the nebulous matter

into distinct masses. The idea of the sun's being a perpetually cooling body seems of necessity to involve that of its having been originally a nebula of vast dimensions; consequently there must have been a period when it began to assume the form of a central luminous orb—a period which may have been the commencement of the fourth creative epoch of the Hebrew narrative, as well as any other. The supposition of the sun's having previously existed as a nebula would also sufficiently account for the statement in the narrative, that the earth enjoyed light and heat before the formation of the solar orb—a statement supported by the aspect of the earth's earliest vegetation as discovered in the strata.

The remaining theory—that of the continual generation of motive energy in the sun itself—is easily reconcilable both with the narrative, and with the appearances presented by the strata; for it sets no limit to the period during which the sun may have served as a source of illumination. It would thus allow of an indefinite lapse of time for the accumulation of the sedimentary deposits. This view would be also in harmony with the general statements of the Hebrew narrative; for it would involve the supposition that, for the first generation of solar motive energy, there was needed a special exercise of Divine power, and for its perpetual renewal a like interposition, either in some manner altogether unknown, or else through the medium of created living beings endowed by their Creator with this force-producing faculty.

According to this latter view, the living energy of the Creator might be regarded as being quite as much the primary source of the light emanating from the sun, as the Hebrew narrative asserts it to have been of that primæval light which shone before the sun was constituted a luminary, when the Spirit of God first imparted a tremulous motion to the fluids. If the idea of a living Creator

be admitted at all, it seems impossible to deny to Him the power of thus acting as a prime mover—of generating motion in the material ultimates by the voluntary exercise of his vital energy, and that either directly, or through the intervention of created living beings on whom He may have bestowed the power of acting as prime movers.

The theory that the solar motive energy has its origin in the sun itself does not, any more than its rivals, tend to settle the question of the existence of the terrestrial vegetation before the earth was illuminated by the sun; but none of the three theories throw any obstacle in the way of that conclusion. This point, as already intimated, can be decided only by geological evidence—from the aspect of the buried remains of the primæval vegetation itself. Seeing that aspect is such as to indicate that, during the epoch when the earliest vegetation flourished, the entire globe enjoyed a species and distribution of climate very different from what it has now, this evidence tells most favourably on the Hebrew narrative.

With respect to the glacial period, the existence of which is inferred from geological phenomena, its date must be referred to the latter portion of the sixth creative epoch of the Hebrew narrative, if not to some time after its expiration. It cannot therefore affect any statement contained in the narrative. Three causes might be assigned for the prevalence, during a certain time, of extreme cold on parts of the earth which now enjoy a more genial temperature: 1st. A mere alteration in the distribution of land and water, more particularly as regards the elevation of the land above the level of the sea. 2nd. A temporary diminution in the amount of heat derived by the earth from the sun. 3rd. The passage of the solar system through a portion of space, in which the ether might be more than usually quiescent, owing to the sparseness of bodies capable of exciting in it vibratory

motion. The second supposition is excluded by the theory of the sun's being a cooling mass; for it presupposes the sun to have always been, from the commencement of its existence as a central orb, hotter than it is now. This theory is therefore reconcilable only with the first or third supposition. But either the meteoric theory, or that of the generation of motive energy in the sun itself, without excluding the first and third alternatives, also admits of the second. For there may have been in the past a period when the sun gave forth less light and heat than it does now — such diminution being due, according to the meteoric theory, to a scarcity of meteors falling into the sun at that particular period; or, according to the other view, to there being, for a certain time, a diminution in the amount of motive energy generated in the sun itself. Any one of these suppositions may be entertained without in the least degree affecting the statements in the Hebrew narrative, which passes over the glacial period in silence.

If the foregoing views be correct, the conclusion of necessity follows, that the fourth *yom* must have been a period separated from the present by an interval of several millions of years; for the sedimentary deposits being indubitable evidence of solar action upon the earth in the formation of torrents and rivers, these deposits are of such vast extent that millions of years must have been occupied in their accumulation. There are, furthermore, among the stars, which were first constituted centres of illumination during the fourth epoch, large groups whose distance from us is so vast, that their light could not as yet have reached the earth, unless it had started on its journey at an immensely remote epoch. Now the statement, that the stars were constituted centres of illumination during the fourth creative epoch, rests on evidence quite as good as that which supports any other averment in the

narrative; while, if that fact be admitted, it of necessity follows that the fifth and sixth *yomim* of the narrative must have been periods of indefinite duration.

With regard to the fourth *yom* itself, it was, like its forerunners, characterized by an *erev* and a *voquer*. At its commencement, the numerous bodies scattered throughout space would seem to have been concealed from each other; for an universal vibratory condition of the ether might exist without the transmission by any of those bodies of an appreciable amount of reflected light one to another. The centralization of the light in the heavenly luminaries, however, would disclose the whole sidereal system; nor do we know of any other means by which its structure could have been displayed. There was thus a concealment and a disclosure characterizing epoch the fourth.

During this period the creative processes, in so far as the earth was concerned, appear to have been suspended. At the end of the third epoch the dry land was left covered with vegetation, and the condition of things was such that it had not yet rained upon the earth. The absence of rain involves the absence of rivers; while if there were no rivers there could be no wearing down of the soil; consequently no formation of sedimentary deposits containing the remains of the primitive vegetation with which the soil was clothed. The chief design of that vegetation appears to have been, as already pointed out, to withdraw from the atmosphere a large portion of its carbon, and so fit the air for animal respiration. The centralization of light would likewise seem to have been needful to adapt the earth to become the abode of animals. It is accordingly remarkable that, in the Hebrew narrative, the centralization of light in the sun is placed between the first introduction of vegetable life and that of animal life upon the earth.

CHAPTER VII.

THE FIFTH CREATIVE EPOCH.

The work of the fifth creative epoch appears to have been the storing of the ocean and other waters of the globe with aquatic animals, and also the introduction of the feathered tribe. In regard to the latter, our English version conveys a somewhat erroneous impression of the meaning of the Hebrew narrative. It reads as if the waters were commanded to bring forth fowl, whereas the original says simply, 'Let fowl fly on the face of the expanse of the fire-fluids'—on the limits as it were of the vast regions of the ether. In verse twenty-one also, the winged fowl are separated from the creatures which the waters brought forth abundantly; for they are specially connected by the particle *êth* with the verb 'created,' by which the Divine action is expressed.

The conclusion deduced from the phenomena of star-light, in regard to the duration of this and the succeeding creative epoch, is strengthened by the aspect of the strata containing the remains of the animal tribes which were created at this period. For it appears to have been at this time that the immense strata of coral and nummulite origin were formed; while these are of such vast extent and thickness, that many ages must have elapsed during the course of their construction by their tiny architects. There are found in the strata, moreover, whole generations and races of marine animals and vegetables, which

must have successively lived and died in the places where their remains occur; nor does it appear possible to set aside the united evidence furnished by these phenomena, and by the astronomical fact of the period required for the transmission of light from the most distant stars, demonstrating that the *yom* was not a mere terrestrial day, but a period of immense duration.

The appearances presented by the strata indicate the continuance of the creative process during the whole course of this epoch—the sea and the land meanwhile undergoing repeated partial changes of level, of which the general tendency was to increase the extent of the latter. The successive races of organic beings seem also to have been adapted to the varying condition of the land and water, as respects position and temperature. It is to this epoch then that we must assign the deposition of the strata containing organic remains, whether of plants, aquatic animals, or birds, underlying those which contain the remains of land animals.

While the first occurrence of the remains of such animals as the foraminifera, polycystina, corals, sponges, and other zoophytes in the strata, is sufficient evidence of the period of the first introduction of animals of this class into the ocean's bed, the first occurrence of the remains of shore plants in the strata is no evidence of the period of their first introduction on the face of the earth. It is merely evidence of the period when there came into operation forces, by which an already existing land vegetation began to be carried down by rivers, and spread over the bed of the ocean.

It has been previously pointed out that, owing to the entire dependence of animal organisms on already organized materials for their subsistence, it is necessary to suppose vegetable organisms to have had the precedence in the order of existence. Moreover, from the fact

that the earliest animal remains found in the strata are those of organisms which nourish themselves by the absorption of organized matter diffused through the water, it follows that a very considerable interval must have elapsed between the first introduction of those animals and that of the previously existing vegetation, in order to allow time for its gradual decay, and the diffusion of the materials which it had organized through the waters, and their accumulation at great depths.

This circumstance tends to corroborate the order of events given in the Hebrew narrative, which makes vegetable organisms to have had their origin during the third creative epoch. But it is needful to suppose the marine as well as the terrestrial vegetation to have begun to exist during that epoch. The simplicity of aquatic plants in general, and of marine plants in particular, indicates that they were most likely first in the order of their creation—the Diatomaceæ, the Desmidiæ, and other unicellular plants, probably taking the lead.

There is, indeed, a peculiar consistency in the order of events given in the Hebrew narrative, which is overlooked by those who imagine the light of the first day to have been that of the sun. Had the narrative placed the establishment of the heavenly luminaries before the clothing of the dry land with vegetation, and also made this latter event to have preceded the introduction of animal life into the waters of the globe, such an order of events would have been contradicted by the phenomena of geology; for solar light and a terrestrial vegetation could not have subsisted together for any length of time, without the destruction of a portion of the vegetation through the agency of rains, torrents, and rivers, which the action of the sun would inevitably have produced.

Thus the remains of the terrestrial vegetation would have been found in the strata before those of any marine animal organisms. But the fact that the latter, and these only of the lowest type, occur before the former, and that too in the very earliest deposits produced by the wearing away of the dry land, proves the first manifestations of animal life in the waters to have begun very soon after the first action of those forces by which the dry land is being continually worn away. These forces are brought into play by the solar influences, so that the development of animal life in the waters seems to have commenced almost immediately after the centralization of light and heat in the sun.

While the occurrence of marine animal remains in association with the earliest sedimentary deposits indicates that the state of things, during which it had not yet rained on the earth, ceased as early as the fifth epoch, we have still more decided evidence of its cessation in the phenomena presented by the strata deposited subsequently to the introduction of land animals, and whose formation must be referred to the sixth epoch, as will be shown in the sequel.

The fifth *yom*, like those which went before it, had also its *erev* and its *voquer*, its periods of concealment and development. At its commencement, the vast mass of materials out of which the various animal structures formed during that period were composed—the carbon, the lime, the silica, the ammonia, and all the other ingredients entering into the organisms—lay mingled with the elements of the ocean or the earth, and concealed in their bosom; but life, emanating from the Fountain of Life, eliminated those materials, brought them forth from their concealment, and disclosed them in countless forms of wonder, from the minute organisms whose beautiful structure

excites the admiration of the philosopher who examines them under his microscope, to the huge megalosaurus, whose gigantic bones and teeth astonish the miner when he stumbles on them embedded in some solid mass of stone.

CHAPTER VIII.

THE SIXTH CREATIVE EPOCH.

THE sixth epoch is that of which the Hebrew narrative gives the most detailed account; for, after the general summary of events in the first chapter, the subject appears to be resumed with further particulars in the second.

Nothing can be plainer than the intention of the narrator to segregate Man from the lower animals in his account of their first origin. Of the lower animals it is affirmed, that God commanded either the waters or the earth to bring them forth; but, with respect to man, it is averred that God said, 'Let us make man in our image, after our likeness.' Then it is added, 'So God created man in his own image; in the image of God created He him, male and female created He them.' It will be observed that the verb employed is here varied—'make' and 'create' being applied to the same act; so that this passage lends no countenance to the idea that the human organism was instantaneously created. In the second chapter, it is affirmed that God *fabricated* the man of dust of the ground.[1] Whether the authorship of the second account be the same as that of the first, or not, is immaterial. The expressions used in the second narrative suffice to show that its author did not understand the statement contained in the first to imply an instantaneous creation.

Another Hebrew writer, the author of the 139th Psalm,

[1] See note Z.

indicates that he also did not consider the human organism to have been at first formed instantaneously. This much may be gathered from the expressions contained in the fifteenth and sixteenth verses of that beautiful poem. Our English translation is rather too much amplified, although it doubtless conveys the general idea intended to be expressed. But, for the present purpose, it is needful to render it more exactly, thus—'Not hid was my strength from Thee, when I was made in secret, curiously wrought in the lower parts of the earth. My substance thine eyes beheld, and in thy book all of them were written, the days they were formed, when not one among them.' His speaking of his having been curiously wrought in the lower parts of the earth indicates that the Psalmist here refers—not to his own development in his mother's womb, but to the first origin of the human organism, when it was fabricated out of the dust of the ground. The word rendered 'strength' may refer to that organizing power with which the first organizer of the human species was endowed by the Creator, and which has been transmitted without interruption to all his descendants. The action of this power was not hidden from the Deity, when, in virtue of it, the first human organizer in secret curiously wrought his organism in the lower parts of the earth. The word rendered 'substance' means the raw material out of which anything is formed. The Deity beheld this material all the time it was being curiously wrought. The Psalmist's speaking of all those things that were formed, as having been written in the Divine book, is a poetical mode of expressing their having been all previously planned in the Divine Mind. But what were the 'all of them' that were thus written? Whatever they may have been, they were formed not all at once, but on successive days, and previously to their being thus formed there was not one among them. According to the strict

construction of the sentence, the word rendered 'substance' must be regarded as a collective noun, and the 'all of them' must refer to the constituents which it embraces. The passage would accordingly be rendered clearer by translating it thus—'My rudiments thine eye beheld, and in thy book all of them were written, the days they were formed, when not one among them.' There is here evidence of the writer's understanding that there was a succession of days in the formation of the rudiments of the human frame, when first elaborated in the lower parts of the earth, and an absence of all idea of their having been assembled and put together in a moment of time.

From the statement in the first chapter of Genesis, taken alone, it would appear that the male and female human frames were fabricated simultaneously. It is only in the second account that a different origin is assigned to the woman. But of that presently.

Man's being made in the image and likeness of God is to be understood only of the human organizer, not of the organism. The likeness to the Creator was to consist, not in the outward form, but in the mental powers and faculties of its organizer; for the Deity, being a pure spirit or mind, can have neither body nor visible form, but, in virtue of his omnipresence, has for his organism the boundless universe. God, having created the human organizer, and endowed him with the requisite powers, constituted him the agent for the elaboration of the human frame.

There is nothing in this statement, nor in the subsequent averment with respect to man's having been formed of the dust of the ground, to indicate the manner in which the organism was fabricated. By 'dust of the ground' ought to be understood the material elements of which the human frame is composed, which were reduced

to a state of extreme division for the purpose. Ordinary dust consists mostly of the powder of alumina, silica, and lime; and had man been formed of such dust, these would have been the ingredients of his organism. But its true constituents are carbon, oxygen, hydrogen, and nitrogen, with a little lime and still smaller quantities of sulphur and phosphorus. Such then must have been the composition of that dust of which Adam was formed. The Hebrews probably knew nothing of any of those substances, excepting the carbon, the lime, and the sulphur; so that they used the general term 'dust' to denote the plastic material which went to form the first human body.

The special averment contained in the second chapter, that God, after forming man of the dust of the ground, breathed into his nostrils the breath of life, and man became a living soul, indicates that then, as now, the human organism was elaborated in such a situation as to exclude the possibility of breathing, and that it was not until it had attained complete development that it was introduced into the atmosphere, and began to inhale the life-sustaining air.

From the foregoing considerations it may be fairly concluded, that there is in the Hebrew narrative no warrant for the notion that the human organism was formed in a state of complete perfection, by a sudden concourse of material ultimates—a notion involving the incongruity of an infant mind in an adult body. The expressions employed are more favourable to the idea, that the organism was elaborated by some gradual process. Beyond this point, however, the narrative gives no instruction, no information to guide us in acquiring a notion of the manner of operation by which the first human form may have been gradually elaborated out of its material elements. Conjectures based on analogy are here our only resource.

The most probable of these have been already indicated, and shown to be easily reconcilable with the narrative.

It is necessary now to examine more particularly the statements respecting the first human pair contained in the second account, which begins at the fourth verse of the second chapter. The sudden change of style and the abrupt introduction of the sacred Tetragram raise a probability that the second narrative may be of much later date than the first, and of different authorship. The absence of the Tetragram in the first account renders it possible to regard it as the substance of a tradition that may have been handed down from very early patriarchal times; but as the Tetragram was first introduced into any writing by Moses, the second account must be either from his pen, or from that of some later writer.

There are in the second narrative certain peculiarities which render it expedient to view it in two aspects—first as history, and secondly as poetry or parable.

There are two material points in which the second narrative appears to differ from the first. In the first, the creation of the land animals and birds is said to have preceded that of man—a fact attested by the strata; and it is averred that, after man had been created, God rested, or ceased from creating any more. In the second account, it is affirmed that God, after having created man and placed him in the Garden of Eden, formed out of the ground every beast of the field and every fowl of the air, and brought them to Adam to be named. Again, in the first account it is averred that God created man male and female; while in the second it is stated that only the male was fabricated in the first instance, that he lived alone for a considerable time, during which he named the lower animals, and that ultimately the female was formed out of his substance by a most peculiar process.

It is by no means easy to reconcile these discrepancies,

while holding the second narrative to be historical as well as the first. If we suppose that the animals, mentioned in the second account as having been formed out of the ground after the fabrication of the man and brought to him to be named, were a new set, designed to replace the set which had been formed before him, but which had subsequently been destroyed, we are met by the difficulty arising out of the assertion, that after the creation of man God rested. The writer may have intended to say, that the Creator *had* formed out of the ground every beast of the field and every fowl of the air, and He brought them afterwards to Adam to be named; but the imperfection of the language at his command may have prevented his conveying this idea with sufficient precision, and he may be understood as referring to the first account, for the true order in which the land animals and man were respectively introduced into the world. Or he may have intended to intimate that the sixth creative epoch did not terminate till after the formation of woman, and that between this event and the first formation of the man there intervened a long interval of time, in the course of which God formed out of the ground the now subsisting races of beasts and birds—causing them to pass in review before Adam to be named. If this last be the true meaning of the second narrative, it would indicate an opinion on the part of the writer, that the races of beasts and birds, which are mentioned in the first account as having been formed before the man, had perished — so rendering necessary a fresh supply.

The other discrepance between the first and second account is more important and involves greater difficulties. Doubtless the statement in the first account, that God created man male and female may be regarded as quite general, and the second account as giving the particulars of the manner in which the male and female were seve-

rally formed; but the account given of the formation of the woman is so very curious, as to demand special attention.

The idea popularly entertained, as deduced from this account, is that the Creator, having caused a deep sleep to fall upon Adam, opened one of his sides with some sharp instrument, extracted one of his ribs, closed up the wound with flesh, took away the rib, and having miraculously transformed it into a woman, brought her to Adam, who, on seeing her, exclaimed, 'This is now bone of my bone and flesh of my flesh.' When the passage is carefully examined in the original, however, it will be found to be capable of being quite otherwise interpreted. There is nothing said of the use of any sharp instrument, nor of the making of any incision in Adam's side, nor of the actual extraction of one of his ribs. The averment is, that after having thrown the man into a deep sleep, the Deity took one from among his ribs, and either closed up flesh instead of it, or enclosed flesh under it—the words used in the original being capable of conveying either of those ideas.[1] The verb here rendered 'took' does not of necessity involve the idea of extraction. It may mean simply that the Deity appropriated one of the ribs to the particular purpose He had in view. There being nothing averred as to there having been made any opening in the side of the man, this idea of mere selection and appropriation to a particular purpose is to be preferred to that of extraction. But if simple appropriation be meant, and not the actual extraction of the rib, the translation 'enclosed flesh underneath it' would be much the better of the two; and we should understand by this expression that there was a cyst formed under the rib—a portion of Adam's flesh being enclosed in a mem-

[1] See note AA.

branous cell. Then it is affirmed that the Deity 'built the rib which He took from the man into a woman.' It is averred, not that He made the rib a woman, but that He built the rib *into* a woman—an expression implying that the substance of the man's rib was part of the material used in the elaboration of the female organism. But from Adam's afterwards saying, 'This is bone of my bone and *flesh of my flesh*'—and again, 'She shall be called woman, because she was taken out of the man'—we are led to infer, that not only the rib, but a portion of the man's flesh was also appropriated to the formation of the woman. The expression 'she was taken out of the man' implies that she derived from him her whole substance, and not merely a part.[1] This language would apply with strict propriety to the formation of the infant female out of the male by some gradual process, resembling that of gemmation in the lower organisms. And were we to be tied down to a rigidly historical interpretation of the narrative, some such explanation as this would be preferable to the popular notion, that the Deity, having assumed the human form, actually extracted a rib out of Adam's side, and miraculously transformed it into a full-sized woman. This latter interpretation is so inherently improbable, it conveys notions of the Deity so humanesque, and of the divine procedure so utterly dissimilar to what the reasonable mind, instructed by observation and experience, conceives of the modes of operation of the Eternal, All-pervading Mind, as exhibited even in the most marvellous of natural processes, while it is so like a tale of magic, that, were the language incapable of any more refined interpretation, there would be left no reasonable alternative save to regard this account of woman's origin as either an allegory or a parable. It is only by under-

[1] See note BB.

standing the language to be descriptive of some natural process analogous to gemmation, that the narrative could be reasonably accepted as historical truth.

It must be owned, however, that, irrespective of the difficulties involved in this account of woman's origin, the evidence tending to prove the portion of the present book of Genesis comprehended between ver. 4, chap. ii. and the end of chap iv. to be an oriental parable is of no mean strength. A simple inspection suffices to show this to be a separate book, distinct both from the first narrative and from that which begins at chap. v.; while the introduction of the sacred Tetragram excludes the supposition of its having been written before the time of Moses.

It is remarkable that no allusion whatever to the trees of the garden of Eden or the story of the fall occurs in any other book of the Hebrew scriptures earlier than the prophecies of Ezekiel, who makes a distinct reference not to the fall, but to the trees, and that in a sense so metaphorical as to indicate his having regarded these trees not as realities, but as symbols (Ezek. xxxi. 9, 16, 18). It is plain, moreover, from the mention made of it in 2 Kings xix. 12, that Eden was the name of a country well known in those days, and that it was, probably from its beauty and fertility, called 'the garden of God.' This country was not an unknown, antediluvian region, but one of those conquered by the King of Assyria, and embraced within his empire. It is mentioned by Isaiah, Joel, and Amos, as well as by Ezekiel; but none of these writers, except the last, make any allusion to its trees, and not one of them refers to the story of Adam and Eve in connection with this 'garden of God.'

There is thus raised a probability that the author of the book concerning the garden of Eden may have been either Ezekiel himself, or some other writer of the period

of the Babylonish captivity, and that it was the substance of some ancient Mesopotamian legend which the writer engrafted on the original Hebrew history of the Caucasian race. The metaphysical names given to two of the trees of the garden afford a strong presumption of their being symbols or metaphors; while the rules of sound criticism teach us to regard the introduction of talking animals into any narrative as a proof of its being a parable or poem.

These particulars, taken together, form a strong body of evidence in favour of the view that the narrative in question is of the nature of a parable or poetical legend rather than a history. But if this view be admitted, it may be deemed necessary to suppose that there existed some more primitive but meagre narrative or tradition of the same or similar events, which furnished materials or outlines to the author of this parable, whoever he may have been, and that he only gave the old legend its present symbolical and dramatic form. The question, however, is involved in so much doubt and obscurity, that to expect anything like a certain conclusion is vain.

If the idea of the narrative's being historical is to be abandoned, and that of its being a parable or allegory is to be preferred, it becomes of comparatively little moment what interpretation be put on the account which it gives of woman's origin. The narrator might have meant it to be understood as the substance of a vision that passed through the mind of Adam, during the profound sleep or trance into which he represents him to have been thrown. Or he may have intended it simply as a poetical introduction to the moral which he draws from it when he says, 'Therefore shall a man leave his father and his mother, and shall cleave unto his wife, and they shall be one flesh.' As Adam, supposing him to have been the solitary first man, could at that moment know nothing of the relations

of father, mother, and wife, these appear to be the words of the narrator.

It is nevertheless possible that the writer may have intended to represent those words as having been spoken by Adam, and this even if the narrative be historical. For it was a general practice among ancient historians to compose the speeches which they introduced into their narratives, as having been spoken by the persons to whom the history relates. That this practice was adopted by the author or authors of the book of Genesis there are several proofs. For example, it is plainly averred in Exodus vi. 3 that the name represented by the sacred Tetragram was unknown to the patriarchs. Nevertheless, in not a few of the speeches which are put into the mouths of the patriarchs this name is introduced, thus showing those speeches to have been composed by a writer acquainted with that divine appellation. Again, in Gen. xviii. 20, 21, the Deity himself, introduced under this name, is represented as having uttered words so inconsistent with the doctrines of the Divine omnipresence and omniscience, as to prove the speech to have been the composition of a narrator ignorant of those doctrines, or who at least had lost sight of them at the moment of his writing. So, in the case before us, if the narrator intended to represent the words, 'Therefore shall a man leave his father and his mother, and shall cleave unto his wife,' as having been spoken by Adam, he would appear to have lost sight of the circumstance that at that moment Adam, on the supposition of his being the first and then only existing man, was not likely to have known anything of the relations there specified. This consideration renders it more probable that the words in question constitute a deduction made by the narrator in his own person.

Again, in the speech put into the mouth of Cain (Gen. iv. 14), there is implied a knowledge of the law of blood-

revenge, while it also involves the idea of there being other men on the earth at the time besides Cain and his father Adam, who, after the death of Abel, were the only men mentioned in the narrative as yet existing. The same conclusion, as to the existence of other families of mankind at that time in the world, might be drawn from the statement that Cain went and dwelt in the land of Nod, that his wife bare him a son, and that he built a city which he named after his son. If the speech put into the mouth of Cain be regarded as the composition of the narrator, that would be an adequate explanation of the knowledge of the law of blood-revenge which it betrays; but, at the same time, it would indicate the opinion of the narrator that there were, at that period, other men upon the earth besides Adam and Cain. If, again, the speech was really spoken by Cain, it would prove him to have been aware of the practice of blood-revenge among already existing communities of men, into whose society he was about to be thrust on his being expelled from his father's home. Should it be suggested that the men of whom he was afraid might have been other sons of Adam, of whose existence the narrative gives no other hint than what this speech affords, the answer is plain. If there were other sons of Adam whose birth is passed over in silence, there may have been also other families of men of whose existence we have only this obscure indication.

It will be seen from these observations, that the questions of the unity and antiquity of the human race are left by the Hebrew narratives quite open. These questions have excited much attention of late, many evidences having been recently discovered of the existence of primitive races of men of unknown antiquity. Some inquirers, who have carefully investigated the matter, have been led to the conclusion that those races were probably older than the Caucasian, of whom alone the

Hebrew scriptures give any account. A fair statement of the evidences, and of their bearing on the narratives, will be found in Dr. McCausland's 'Adam and the Adamites.'

The discovery of flint implements and human remains, in association with the bones of extinct animals, in caves and very old deposits, are certainly strong evidences of the existence of races more ancient than the Caucasian. The making of implements of brass and iron is stated in the record to have been practised by the early descendants of Cain; and it may thence be fairly argued that the flint implement makers were an earlier race, more especially as their remains have been found in the western parts of Europe, far from the centre whence the more highly endowed Caucasians spread themselves. Again, the Negro is represented on very ancient Egyptian monuments; while there was scarcely time, between the creation of Adam and the date of those monuments, for that variety of the human species to have been derived from the normal type by the accumulation of small modifications. It is consequently open to conjecture, that this race may have been from the first distinct, and more ancient than the Caucasian. There is no mention whatever in the Hebrew scriptures of the origin of either the Negro or the Mongolian races; and this silence leaves the field of research with respect to those races perfectly open. The Chinese may be as old as they claim to be, for aught that the Hebrew scriptures say to the contrary, seeing their existence is altogether ignored.

It cannot be confidently affirmed, however, that the evidence accumulated up to the present time is sufficient to establish the existence of races of men older than the Caucasian. There is no force in the argument based on the distinction between the name 'Adam' and the other Hebrew name of man, '*Ish*,' as it has been stated by Dr. McCausland, who would appropriate the former to the

Caucasian race exclusively, and apply the latter to the other races. For Adam derives the name *Isha*, woman, from *Ish*; saying, 'She shall be called *Isha*, because she was taken out of *Ish*;' thus applying the latter name to himself: so that he was both *Ish* and Adam. Dr. McCausland's argument would have been good only had *Ish* been used in the first account of the creation of man, contained in Genesis i. 26, 27; whereas the word used there is 'Adam;' while the same name is applied to the individual man, whose formation from the dust of the ground is mentioned in ver. 7, chap. ii. On the other hand, from the use of the plural in ver. 2, chap. v., it is left open to conjecture that there may have been primarily created more than one man to whom the name 'Adam' was given; although the second narrative confines attention to one particular Adam as being the progenitor of the Hebrews.

Should the evidence then ultimately prove sufficient to establish the existence of races of men older than the Caucasian, it would not be difficult to reconcile the Hebrew narrative with such a state of the fact. 'Adam' was the name given to the primary man, by reason of his being fabricated out of the ground.[1] That there was more than one called 'Adam,' from being thus separately formed, might be fairly inferred from the statement in ver. ii. chap. v., 'And He called *their* name "Adam," in the day when He created *them*.' It might be argued that the plural could scarcely be meant to embrace Eve, seeing that, according to the narrative in chap. ii., she was *Isha*, the issue of *Ish*, and was therefore not formed out of the ground; so that the name 'Adam' was inapplicable to her. It is never used in reference to any other than to the ground-made man. Thus Eve speaks

[1] אדם man, from אדמה the ground.

of her first-born as *Ish*; while the same word is applied by Lamech in reference to the man he had slain. If, then, there were more than one to whom the name 'Adam' was given, they must have been primitive men, formed, like the first Caucasian, out of the ground; for only to such could the name properly apply.

Now if it be borne in mind that the sixth creative epoch was, in all probability, a very long period of time (and the evidence on this point will be more fully developed presently), there is nothing to bar the supposition that long intervals may have intervened between the introduction of the several races of men into the world, and that each race may have started with a new type elaborated out of the ground. There may have been even a progression in the series of types—the lower preceding the higher—as we observe to be the case among the species of the lower animals. This idea of succession, however, is not of necessity involved in the hypothesis of there having been more than one primary race of men. There may have been a Negro Adam, a Mongolian Adam, and perhaps two or three more besides the Caucasian Adam; all introduced into the world at nearly the same time, but placed at distant centres on the face of the earth. Nevertheless the idea of their having been introduced in succession has this advantage, that much of the difficulty in reconciling the second narrative with the first would be removed by supposing that the first applies to the earlier Adams, and that they were formed male and female; while the second applies exclusively to the Caucasian Adam, it being only in his case that the female was made his issue in the manner there described.

The adoption of this view would further remove much of the obscurity in which the second narrative is involved. We should then be at liberty to suppose Cain to have

become acquainted with men of another race; to have heard of the law of blood-revenge as practised among them, and to have consequently been afraid of being driven from his own family into the midst of those strangers. We should then be at no loss to discover where he obtained his wife, or who helped him to build his city Enoch, or by whom it was inhabited. Much of the mystery would also be removed from the statements contained in Genesis vi. 1, 2, 4. For we should then understand by 'the sons of God' the descendants of the Caucasian Adam, so called by a Hebrew idiom to denote their superiority, in the estimation of the narrator, to the other races, whose daughters are called the daughters of men.

The whole subject of the unity and antiquity of the human race, however, is still involved in too much obscurity to admit of the formation of any decided opinion. All that has been attempted here is to show that there is, in the Hebrew narratives, nothing inconsistent with the hypothesis that there may have been several primitive races of men, each starting from an Adam—a man formed from the ground by some gradual process analogous to those by which, even at the present time, perfect organisms are slowly elaborated from the most minute and rudimentary organic elements.

Whether the narrative commencing at Genesis ii. 4 be history or parable, it is valuable as showing the opinion entertained by its author with respect to the duration of the sixth creative epoch, and inferentially of the others. Reviewing the events of this epoch as recorded in the first and second narratives, we have first the creation of various tribes of land animals, followed by that of man. We have next the statement with respect to the man's being placed in the garden of Eden, and to the formation of land animals, cattle, wild beasts and birds, and their

being brought to Adam that he might give them appropriate names. This is followed by the averment that all this while Adam was without a suitable companion. We have then the throwing of the man into a profound sleep, and the formation of the woman out of his substance. This last event must, according to the first narrative, have happened before the termination of the sixth epoch. Looking then to the whole series of those events, there are strong grounds for concluding that the narrator of the second narrative himself regarded the sixth creative epoch, during which they are stated to have all occurred, as having been some much longer period of time than a single day of four-and-twenty hours.

Observe, in particular, Adam's review of the various races of land animals, including cattle, wild beasts, and birds, and his giving them names expressive of the peculiar characteristics of each, derived from a careful observation of their diverse instincts and habits. We have here the actings not of the Almighty, the Eternal, with whom a thousand years are as yesterday when past, but of a finite human being. We must consequently infer the lapse of a period of time proportioned to the work to be accomplished. The man had to study the science of zoology, and to invent a language to express the ideas acquired in the course of that study. A moment's reflection will show that a single ordinary day was insufficient for such a purpose; while there is nothing to indicate that the narrator himself intended it to be understood that all these events occurred within such a limited space of time.

Nor is there, in the subsequent part of the narrative, anything to contradict the supposition that this sixth creative epoch may have extended over a long series of years. The first chronological point in the subsequent narrative is the birth of Seth, which, according to the

Hebrew text, is said to have occurred when Adam was 130 years of age. The Septuagint version has 230 years. This event appears to have happened shortly after the murder of Abel; and, from his having died childless, it may be inferred that he perished in youth. Thus Cain may be reasonably supposed to have been about twenty-five years of age when Seth was born, and Eve may have been about twenty years of age at the birth of Cain. According to this view, the period during which Adam lived alone may have been about eighty-five years, or according to the Septuagint 185 years. Either of these periods would allow ample time for his acquiring a knowledge of the lower animals, and inventing names for them, expressive of the ideas which he had formed from prolonged observation of their appearance, instincts, and habits. Thus even from the narrative itself much may be gathered to favour the probability that its author regarded the sixth creative epoch not as an ordinary day, but as a period of long duration.

The appearances presented by the strata containing the remains of land animals render this conclusion inevitable. They demonstrate that there were numerous successive genera and species of the higher classes, which must have lived and died during the formation of those rocky strata, and become extinct before the human race was introduced upon the earth. The enormous mass of those strata again, obviously formed by some slow and gradual process, renders it evident that long ages must have intervened between the creation of the first land animals and that of man.

The strata of this epoch also present unequivocal evidence bearing on another curious point—the existence of rain; for the same series of rocks which exhibit the earliest traces of land animals contain sandstones having their surfaces distinctly marked by rain-drops. This then

is a still more striking proof of the cessation of the state of things described in Genesis ii. 5, 6 than that afforded by the mere existence of sedimentary deposits, although these are themselves sufficient proofs of the existence of rain. The period when rain had not yet fallen must accordingly have ended before the introduction of land animals, however much earlier.

The *erev* and the *voquer*, the confusion and development, by which the sixth *yom* was characterized, appear to have been of the same kind with those which distinguished the fifth, and therefore require no remark.

If we now review those portions of the Hebrew narrative which relate to the first origin of organic beings, we shall find that the language there employed lends no countenance to the idea of the instantaneous formation of perfect organisms by a sudden assemblage of inorganic atoms. A very special and clear form of expression indeed would have been required to sanction such a notion; but the words used in the narrative suggest quite a different train of ideas.

Our English translation, however, fails to convey with adequate precision the meaning of the original Hebrew. In the three cases of the vegetation, the aquatic animals, and the land animals, the English version employs the same verb, 'bring forth;' whereas the Hebrew text varies the verb in each instance. In the case of the vegetation the divine command is *Tadesheh hâârets desheh*,[1] which would be best rendered thus: 'Let the earth cause to germinate the germ.' In the case of the aquatic animals the command is *Yisheretsu hamayim sherets*,[2] 'Let the waters cause to creep the creeper.' In the case of the land animals the command is *Totseh hâârets nafesh hayâh*,[3] 'Let the earth bring forth the living animal.' Now it is

[1] תדשא הארץ דשא [2] ישרצו חמים שרץ
[3] תוצא הארץ נפש חיה

remarkable that the verb used in this last case is the same as that employed to express the action of the earth in bringing forth the vegetation. *Vatotseh hâârets desheh*,[1] 'And the earth brought forth the germ;' thus indicating that the mode of operation in the case of the land animals was analogous to that of the germination of the vegetation from the soil.

There is a distinction to be observed, however; for while the results of the command in regard to the vegetation are given in the above terms, in the case both of the aquatic and land animals a more direct operation of the Deity seems to be intimated. With reference to the aquatic animals, the verb indicating the act of the Creator is *bârâ*,[2] which, as already pointed out, means to cause existence indefinitely; but it is added that the waters caused them to creep or glide, thus intimating that the intermediate agency of the waters was employed. With reference to the land animals, the verb used to denote the act of the Creator is *âsâh*,[3] which signifies to fashion out of pre-existing materials.

The language employed in the second chapter of the narrative still more decidedly points to a process of construction. The only animal whose formation is narrated in detail is man. The verb denoting the divine action in this case is *yâtsar*,[4] 'to fabricate,' clearly pointing to a process of elaboration from existing materials; while these are stated to have been derived from the ground. The employment of the word *âfâr*,[5] 'dust,' seems to indicate that the elements were reduced to a state of the most minute division, in order to their being absorbed into the organic structure, and assimilated by the organizing power. The same verb, *yâtsar*,[4] is again applied to the case of the lower animals in ver. 19, chap. ii., where it is affirmed that

[1] ותוצא הארץ דשא [2] ברא [3] עשה
[4] יצר [5] עפר

'out of the ground God the Eternal *fabricated* every beast of the field and every fowl of the air.'

In all this language there is nothing whatever to indicate that plants and animals were at first created in a state of perfection, by an instantaneous aggregation of inorganic ultimates, in obedience to a mere determination of the divine will. On the other hand there is much tending to show that both animal and vegetable organisms were formed by some gradual process, and in particular that land animals and plants were both elaborated in an analogous manner from the ground. The idea of their instantaneous creation is thus as destitute of authority from the Hebrew narrative, as it is of support from any known fact.

CHAPTER IX.

DURATION OF THE CREATIVE EPOCHS.

THE main difficulty in reconciling the Hebrew account of the world's first origin with the discoveries of modern science arises out of a misunderstanding in regard to the interpretation to be put on the *yom*,[1] of which six are stated to have been occupied in the work of creation. To hold these to have been terrestrial days renders the difficulty inextricable; nor is such an interpretation required by the Hebrew scriptures themselves. All that is needful is to suppose the week, with its six days of work and seventh day of rest, to have been appointed as commemorative types of the six epochs of creation and the still subsisting epoch of repose. The shortest natural divisions of time have been selected for this purpose, in order that man might be more frequently led to remember his origin and adore his Creator. The alternations of light and darkness, which characterize the natural day, are also apt symbols of the successive recurrence of periods of confusion and development which would appear to have distinguished the creative epochs. It must further be remembered that there was appointed a sabbatical year as well as a sabbatical day, while at the end of every seven sabbatical years there was a year of jubilee; so that it seems to be rather in their sevenfold division

[1] יום

than their duration that the days of the week are types of the epochs of creation.

Did the description given in the Hebrew narrative apply to the earth alone, there might be reason in holding the *yom* to be a terrestrial day; but such a limitation of its scope seems irreconcilable with its general tenor, and more especially with the work of the fourth epoch. If, on the other hand, the narrative describe the first origin, not only of the earth, but of the whole heavenly bodies, it can hardly be imagined that the vast events of universal creation should have been regulated by the periods of the earth's rotation on its axis. A day of earth could have no relation to the illumination of all the suns throughout the universe; while before that event there could have been no such thing as a terrestrial day, in the ordinary acceptation of that term. It appears more probable that if those epochs had any connection at all with the motions of the heavenly bodies, it was with movements common to the whole.

Analogy leads to the inference that not only do the suns composing each of the stellar systems move round their common centre of gravity, but that those stellar systems themselves have their proper motions with respect to each other, and that the nebulæ also revolve either round their common centre of gravity, or in some other cycle, in order to counteract their tendency to indefinite mutual approach. In such a motion every body in the universe would participate, and its periods might therefore be regarded as appropriate measures of the time occupied in those vast processes by which all were more or less affected. If the *yom*, then, was a measure of motion at all, it appears more likely to have been the period of a revolution of the whole stellar systems around their common centre of gravity, than of the rotation of our comparatively insignificant planet on its axis.

There is only one circumstance that apparently favours the idea of the *yom's* having been an astronomical period. On calculating backward the precession of the equinoxes, it is found that the autumnal equinox coincided with the earth's perihelion about the year B.C. 3997, which nearly corresponds to the date commonly assigned to the creation of man. As this conjunction occurs once in about 20,984 years, it might be thence inferred that such was the duration of each *yom*. But nearly the same objection applies to this view as to that of each creative epoch's being merely a terrestrial day—namely, that it makes the motions of only one planet a measure of events in which all participated. Geological considerations moreover require a much longer period. If the above coincidence, then, really indicated the termination of an astronomical period constituting the creative epoch, the latter was more probably one of those long periods, comprising several millions of years, which must elapse before the whole planetary bodies resume the same relative positions which they had at the moment of that coincidence. Nor is there in that coincidence itself anything which should lead us to reject the first idea, that each creative epoch was one of those still longer periods of revolution in which every body in the universe must participate.

No great stress, however, can be laid on the astronomical coincidence in question; for much uncertainty prevails in regard to the true chronology of the human race, there being a difference of upwards of a thousand years between the computations of well-informed chronologers. Recent discoveries moreover have raised a strong doubt whether even the longest of the computed chronologies may not be very far short of the truth. As the first creative epoch seems to have preceded any motion, except the tremors which constituted the primæval light, the more probable supposition appears to be that the *yom* had no relation

whatever either to the rotation of the earth or to the motions of any of the heavenly bodies; but that each epoch was distinguished solely by the commencement and cessation of the particular creative processes by which they were severally characterized, the *erev* and the *voquer*, the confusion and development peculiar to each. The safer conclusion then seems to be, that the six creative epochs were simply the periods of the successive developments of the works of creation, and were distinguished from each other not by any of the various movements of the heavenly bodies, but merely by the nature of the events which happened during their currency. According to this view, these epochs may have been of any length whatever, nor is it necessary to suppose them to have been all of the same duration.

Those who object to this indefinite extension of the creative epochs, and contend for their being regarded as natural days, rest their opinion chiefly on their being defined by an *erev* and a *voquer*, by which they will not understand anything beyond a literal evening and morning. This objection, however, is deprived of all force by a reference to Dan. viii. 14, where the same mode of expression is applied to prophetical days, which are generally allowed by commentators to mean years. In answer to the inquiry how long the sanctuary should be trodden under foot of the Gentiles, it is said, 'Unto evening and morning two thousand three hundred.' So it stands in the Hebrew text. The Greek translation has the number 2,400, thus making each hour of the evening and morning correspond either to a century or 100 days; but this variation is unimportant to the present question. In ver. 26 of the same chapter it is added, 'And the vision of the evening and the morning which was told is true.' In these passages the terms evening and morning appear to be employed metaphorically, to designate the interval be-

tween the setting of the prosperity of the Jewish people and its rising again, a period of 2,300 or 2,400 days or years. This period is described as *one* evening and morning; for these words are in the singular number both in ver. 14 and 26 of the chapter cited. In the latter verse in particular the entire period is designated 'the evening and the morning.' If, then, a period of 2,300 or 2,400 years, or even of as many natural days, be thus characterized as one evening and morning in a figurative sense, with reference to a decline and dawn of national prosperity, it is surely unfair to object to our understanding the epochs of creation to be long indefinite periods of time, merely on the ground of their being each defined by an evening and morning, seeing these terms are capable of such an extension of meaning.

It has been attempted by some of those who cling to the idea of the *yom's* being a natural day to reconcile the Hebrew narrative with the discoveries of modern science, by maintaining that the statement 'In the beginning God created the heavens and the earth' ought to be separated from the rest of the narrative. They would regard that averment as importing that God originally, at some indefinitely remote epoch, created the heavens and the earth; while they would hold all the rest of the account as applying to a mere renovation of the earth from some universal catastrophe, which had shrouded it in darkness and rendered it formless and void. Unfortunately for this assumption, however, the narrative affirms that what God called 'heavens,' namely the expanse (and which must be presumed to be 'the heavens' mentioned in the first announcement), did not exist at all until the second *yom*; while it was not until the third that the Creator formed what He called 'the earth,' which must in like manner be held to be 'the earth' mentioned in the opening sentence, and which is immediately there-

after affirmed to have been previously mere vastness and emptiness, without either limits or weight.

It is clear, then, that the statement with which the narrative begins is simply a general announcement of the creative act, which is in the sequel described in detail. The attempt, therefore, to separate the first verse from the rest of the narrative, and to hold it as referring to an antecedent creation, is even on mere critical grounds inadmissible. This theory, moreover, is altogether undermined by the phenomena of geology. According to this hypothesis, the strata containing organic remains must have been all deposited before the beginning of the six epochs embraced in the narrative, seeing these strata exhibit indubitable evidence that many long ages were occupied in their formation. This idea entails the further supposition that immediately before the period embraced in the narrative there had befallen the earth some great catastrophe, which had extinguished all the previously existing races of plants and animals, leaving the earth entirely covered with water, and the globe completely enshrouded in darkness by an envelope of dense vapours.

This view is not only exposed to all the objections already urged against those interpretations, which it must involve, of the statements relative to the light of the first day, the expanse formed on the second, and the illumination of the heavenly orbs on the fourth day, but it is met by a yet more insurmountable obstacle. The strata themselves exhibit no evidence whatever of any such universal catastrophe as the theory assumes, nor indeed of any sudden break in the continuity of the processes which terminated in the formation of man. On the contrary, they show a gradual increase in the number and variety of the genera and species of organic beings from the less to the more perfect, proceeding not in one, but in several parallel lines of development. In the more

recent formations we find an admixture of extinct and subsisting species; while among the lower organisms, especially the Foraminifera and Diatomaceæ, there are species which preserve their identity and continuity of formation throughout nearly the entire range of the geological epochs. The strata also show that from the period of the first entombment of organic structures down to the introduction of man into the series, both dry land and water must have continuously subsisted. There is thus a total absence of all evidence of the existence, at any period subsequent to the first entombment of organic structures, of such a condition of the terraqueous globe as will answer to the description given at the outset of the Hebrew narrative. The supposed universal catastrophe must therefore be dismissed as destitute of proof.

An attempt has recently been made to elude this difficulty by still further limiting the scope of the narrative, and holding it to apply not to the terraqueous globe at large, but only to a very limited area of its surface. It is imagined that Mesopotamia was the central portion of this area, which may have extended 1000 miles or so in every direction from that centre.

According to this view, the Hebrew narrative dwindles into a mere traditional and rather highly coloured account of a local catastrophe, produced by a great earthquake or volcanic convulsion, resulting in the temporary submergence of the whole of that limited region. The darkness was caused by volcanic smoke, and the first light by its partial dissipation. The stretching out of the expanse of heaven was only the uplifting of dense volumes of watery vapour, and their formation into clouds in the upper regions of the air, where they constituted the waters above the heavens. The gathering together of the waters was only the abatement of the partial flood, and the re-emergence of the dry land. The illumination of the heavenly

orbs was nothing more than the reappearance of the sun, moon, and stars, caused simply by the total dissipation of the dense clouds that had enshrouded the face of the sky. The other steps in the process of renovation consisted merely in the restoration of this limited region to a habitable state of cultivation, and the reintroduction into it of animals, more especially man.

This theory, however, while open to all the objections before stated, except that particular one which it was devised to elude, is exposed to others of a still more formidable kind. For if the narrative describe only the restoration of a limited area from a partial convulsion, there was no necessity for a resort to any creative process at all, in order to its being again clothed with vegetation and stored with animals, seeing these could have been without difficulty introduced from other parts of the globe which had not been visited by this partial destruction. This objection applies with double force as respects the description given in the narrative of the creation of aquatic animals.

That mode of interpreting the narrative, then, which would separate the first verse from the rest, regarding it as an affirmation that at some remote and indefinite period God created the heavens and the earth, supposing the whole of the geological strata to have been formed prior to the commencement of the first day embraced in the narrative, and viewing it as a detailed account of a mere restoration of the earth, or a limited portion of it, from some universal or partial catastrophe, a restoration accomplished in six natural days, must be abandoned as untenable.

With a view to evade the apparent difficulty connected with the six days, it has been suggested that the Hebrew narrative is an account of what was revealed to its author in a vision, while the six epochs are simply the six suc-

cessive natural days, in which the successive scenes of this vision were impressed on the mental eye of the seer, yet corresponding to the six indefinite periods of time occupied in the actual work of creation. To this view, however, there are several grave, if not insurmountable, objections.

Although we have in the Hebrew scriptures many examples of revelations made by vision, yet in every such instance it is expressly declared to have been in vision that the communication was made. But there is here not the most remote hint of the narrative's being the description of a vision. Every sentence is in the form of an averment of historical fact. Moreover this idea of a visible representation involves difficulties far greater than any of those which it was designed to evade. The very first descriptive statement is an insurmountable barrier to such a view—'The earth was vast and void, and darkness was upon the aspect of immensity.' Let any man of ordinary understanding try to conceive how such a state of things could have been represented to either the mental or the physical eye, and the impossibility of such a vision will be at once perceived. The universal darkness excludes the idea of vision. How, amid such an impenetrable gloom, could the seer observe that the earth was vast and void, supposing such a condition to have been capable of being perceived at all? Again, in reference to the work of the fifth epoch, it would be needful to suppose the seer to have been in imagination first plunged into the depths of the sea, in order to perceive the waters beginning to teem with living creatures, and to behold the Deity creating the great sea reptiles, and thereafter to have been uplifted to perceive the fowl beginning to wing their flight athwart the aspect of the expanse of heaven. Lastly, we must suppose the narrator to have in his vision actually seen God take of the dust of the

ground, make thereof the first man in his own image, and breathe into his nostrils the breath of life. If so, why should he have in his first account averred that 'in the image of God created He him; male and female created He them'? seeing it appears from the subsequent more detailed narrative that it was only the man who was first formed out of the dust of the ground, and that it was not till after the lapse of a considerable interval of time that God formed the female out of the male. Had the first narrative been the substance of a vision, would not this very remarkable feature in the scenic representation have been described at once, instead of being left, as it is, to be fully narrated in a totally distinct narrative, differing from the first in style and manner as much as poetry differs from prose? Nothing could stamp the first composition more clearly with the character not of a description of scenic representations, but of a simple narration of actual events, than its summary mode of mentioning the creation of man, more especially as contrasted with the manner in which the separate formation of the male and female is described in the more poetical book which follows. The first statement is simply an averment of the broad fact that God created mankind—male and female—without a hint of the diverse manner of their separate formation, such as would have been given by an eye-witness of the transaction in scenic representation. If there be any vision at all in these early books, it is in the second rather than in the first that we can detect the only features indicating such a mode of revelation.

Nor is there any real gain to be derived from this hypothesis of there having been made to the narrator, in six successive natural days, a revelation by scenic representation in vision of the events of creation. It does not truly obviate any difficulty with respect to the days; for these must still be supposed to have been, in reality, long

indefinite periods of time; and it is better to meet this difficulty boldly and fairly, by adapting our interpretation of the word *yom* to the ascertained facts, than to endeavour to evade it by so fanciful an assumption.

With respect to its other supposed advantage, that it allows of the narrator's describing the successive acts of creation as they would have appeared to the eye of a spectator stationed on the earth, the hypothesis of scenic visions is not required for this purpose. For if the Deity revealed to the mind of the narrator the substance of this narrative at all, He would do so in a manner intelligible to a being of this world. The events would be indicated to the narrator's mind as their occurrence would have appeared to an earthly spectator; this globe being made the centre, as it were, of the universal system, because of its relative importance to the intellectual creature for whose inheritance it had been prepared. It does not appear to have been intended to initiate the narrator into a knowledge of the general structure of the universe. It seems to have been deemed enough to convey to him an intelligible notion of its origin, specific details being given with reference to this globe alone.

This view suffices to account for the very general terms in which the other bodies of the universe are mentioned in the description of the work of the fourth day, and for the prominence given to their relation to this earth among the purposes they were to subserve. But surely the blowing away of a mass of vapours will never satisfy the rational mind, as being an adequate explanation of the phraseology there employed in reference to the heavenly orbs. Nothing will justify the language of the narrative short of the idea that it describes the centralization, in the countless suns that sparkle in the heavens, of the property of exciting those luminous tremors which had previously been produced on the aspect of the universally

diffused ethereal fluids by the direct action of the divine energy.

The hypothesis of a scenic representation in vision accordingly falls to be dismissed, as being alike without warrant and without useful end.

It has been deemed expedient to enter thus fully into the question of the interpretation to be given to the word *yom*, because it is conceived to be the key to the explanation of the entire narrative. Indeed, it is only by giving that word an enlarged meaning that it seems possible to render this account of creation consistent either with itself or with the discoveries of science. Grant that the *yom* was a period of indefinite duration, and the scientific facts will be found, so far from throwing discredit on the narrative, to give it all the support of which the circumstances of the case will admit.

The whole of the phenomena disclosed by geology, except perhaps the formation of some few of the primitive rocks, must be referred to the fifth and sixth creative epochs; for on the earlier epochs geology throws no light whatever. Now the order of events which the narrative assigns to those two epochs agrees with that deducible from the phenomena of the strata. The broad facts which these disclose are simply that the entombment of marine animals, and of both land and water plants, preceded that of land animals; that there was a primitive vegetation on the earth, which bears evidence of its having flourished under a species and distribution of climate very different from those which now prevail; and that this original vegetation began to be destroyed before land animals came to be embedded in the strata. The fact that the remains of this first vegetation are not found in the strata before those of marine animals does not prove that it may not have existed for ages before the latter were created; it merely shows that its destruction had not

begun till after these had come into existence. It proves that the condition of things which caused the entombment of the first vegetation in the strata did not emerge until marine animals had begun to live and die.

Thus the facts of geology and those deducible from the narrative, in so far as they bear on each other, exhibit as great a degree of correspondence as it is reasonable to expect. It must ever be kept in view, however, that geology can throw light on the fifth and sixth epochs only, seeing the very oldest sedimentary rocks contain marine animal remains, and cannot therefore be of earlier date than the fifth of the Hebrew epochs. If these be admitted to be periods of undefined duration, geology may be prosecuted without any fear of its clashing with the Hebrew narrative.

With respect to the period that has elapsed since the land and sea assumed nearly their present relations to each other, and since the continents of the world acquired nearly their present conformation, we have good evidence from two diverse and independent sources. The agreement of these testimonies is so striking as to raise a probability of considerable strength.

There are still in progress of formation on the coast of Florida coral reefs which have been continuously constructed by the same species of polyp; and the commencement of their labours can, by calculation from their average rate of progress, be traced back as far as 30,000 years. Now it is remarkable that calculations made in reference to the attrition of the rocks in the valley of the Niagara, by the action of the celebrated falls, point to nearly the same period of time as having been required to wear down the rocks in the space between Queenstown and the present site of the falls. But it has been further demonstrated that the whole of this vast excavation has been hollowed out by the river subsequently to the

deposition of strata containing fossil shells identical in species with those of some mollusks now living, and also the bones of the gigantic quadruped called the mastodon.

The evidence is thus strong that, during a space of 30,000 years, the conformation of the terraqueous globe has preserved nearly its present aspect, and, that the laws regulating the development of organic nature and the conservation of species have been in continuous operation during that long period. These facts are of themselves sufficient to exclude all other suppositions save that of regarding the creative epochs as periods of indefinite and immense duration.

CHAPTER X.

DIVINE AUTHORITY OF THE HEBREW RECORD.

The question whether the Hebrew narrative of creation be the substance of a divine revelation, or a mere human speculation, may be said to depend almost wholly on two points—the length of the days, and the primæval light; but these differ in their bearing on the issue. Could it be clearly proved to be impossible to hold the days of the narrative to be anything else than the ordinary periods of twenty-four hours, and its evenings and mornings to be anything else than the ordinary recurrences of twilight and dawn, then the attempt to maintain the narrative to be the substance of a divine revelation would be vain. On the other hand, even could it be shown to be legitimate to hold the narrator to have meant by the *yom* a long indefinite period of time, and by the evenings and mornings periods of confusion and development characterizing the several epochs, this would only remove an obstacle to the narrative's being regarded as a divine revelation, but would not establish its claim to that character. For the idea of the work of creation's having occupied long epochs of time is one that might readily occur to the mind of a mere speculator. Of this we have evidence in the fact, that nearly all theorists have contended for long epochs. Hence the narrator's having described these epochs as days, defined by evenings and mornings, could be rendered available as an evidence of

divine revelation only by its being possible to prove the entire work of creation to have been accomplished in six ordinary days of twenty-four hours, which, in the face of the phenomena of geology, is out of the question.

It is otherwise, however, with the statements regarding the primæval light. Were it possible to prove that the light of the first three epochs could have been nothing else than the radiance of the sun partially obscured by vapours, this would be an evidence against the narrative's being a divine revelation so strong that it could not be overcome. For nothing can be plainer than that the narrator intended to convey the idea that the light of the first three epochs was not that of the sun, and that it was not till the fourth epoch that our great luminary began to shine. Even could it be made to appear probable that the intention of the narrator was the reverse—that he meant the light of the first three epochs to be understood as nothing else than that of the sun glimmering through mists and vapours which obscured his disc—nothing would be done towards establishing the probability of the narrative's being a divine revelation. For the idea that the light of our globe could never have emanated from any other source than the sun, and that his disc might have been at first obscured by vapours, was one that might have readily occurred to a mere theorist. And of this there is sufficient proof in the circumstance, that almost all speculators have contended that the light of the first three epochs was nothing but the radiance of the sun, glimmering through vapours so dense as to render his disc and those of the moon and stars invisible.

This view has been taken not only by those who uphold the natural day theory, but even by those who maintain the days to have been long indefinite epochs. With the former this notion is excusable; for there is nothing very improbable in the supposition that for three ordinary

days the whole earth may have been so completely shrouded in vapours that, although the sun shone upon it, his disc remained invisible. But the supposition that this condition of things lasted for three epochs, each comprehending many thousands of years, is a little too extravagant.

On the other hand, if it can be shown to be probable that the light of the first three epochs was not that of the sun, in that same degree will it become probable that the narrative is the substance of a divine revelation. For the chances against the supposition that any mere theorist should have imagined such an order of events are immense.

The evidence in favour of the primæval light's having been other than that of the sun rests primarily on the undulatory theory. If light consist of emitted shiny particles, these must obviously have a centre of emanation. But if light be merely vibratory motion, the supposition of a special centre of undulation is unnecessary. Of the absence of this necessity we have evidence in the aurora borealis, whose light does not proceed from any special centre of undulatory force. But the undulatory theory and the aurora borealis only remove a difficulty in the way of the supposition that the primæval light was not that of the sun: they do not establish the fact. The only thing in the shape of direct proof which is at all available is the appearance presented by the vegetable remains contained in the rocks of the coal formation. These remains, wherever found, whether in the arctic or tropical regions, have all one character, which indicates the prevalence of an uniformly warm and moist climate over the entire surface of the earth, for a very long period of time. A climate of this nature could not subsist under the present arrangements for supplying the light and heat of the globe. Even the extravagant supposition that the obliquity of the ecliptic might have been at one time so

great as to render the sun each year nearly vertical over either pole, will not elude this difficulty. For under such an arrangement the amount of light and heat received by our planet from the sun would not be greater than now, and nothing like an uniform climate would be produced. There would be every year one or two short, hot summers; but these would be succeeded by correspondingly cold winters, which would be fatal to such a vegetation as that whose remains are found in the coal formation.

On the other hand, it must be allowed to be probable that during the epoch when that primæval vegetation flourished the quantity of carbonic acid gas in the atmosphere must have been greater than it is now—all the carbon of the vegetation which succeeded that whose carbon is entombed in the strata having, while the latter flourished, been in the gaseous condition, and subsequently withdrawn to fit the air for animal respiration. This circumstance would of itself tend to increase the power of the atmosphere to convert the undulatory motion of the ether into heat. Still, while the general warmth of the air might thus be augmented, it seems impossible to account in this manner for the temperature's being as high at the poles as at the equator; while the character of the primæval vegetation shows that such was the case. The simplest explanation of this phenomenon is, that the light and heat of the globe were, during the subsistence of that vegetation, maintained otherwise than by the solar rays.

It thus appears that the whole *direct* evidence supporting the claim of the Hebrew narrative of creation to be regarded as the substance of a divine revelation, is concentrated in this one point of the uniform tropical character of the vegetable remains found in the strata of the coal formation. For that character tends to confirm the truth of the statement contained in the narrative, that

during the subsistence of its earliest vegetation the globe derived its light and heat directly from the ether agitated by a special exercise of the divine energy, before the sun and stars had been constituted centres of undulatory force —an idea most unlikely to have entered the mind of the narrator otherwise than by divine inspiration. Every attempt, therefore, to weaken the strength of this evidence, by trying to prove the light of the first three creative epochs to have been merely that of the sun glimmering through dense clouds and vapours, is equivalent to an effort to reduce the Hebrew narrative to the level of a mere human theory.

Even at the best, the evidence, furnished by the tropical character of the remains of the primæval vegetation under every latitude, goes no further than to establish the divine authority of the narrative as a fair and reasonable probability; but this is all that, under such difficult circumstances, we have any reason to expect.

There still remains, however, an obstacle not yet noticed to the narrative's being held, as it now stands, to be in its integrity a divine revelation. This difficulty arises out of the expressions imputed to the Deity in verses 29 and 30, relative to the provision for the food of man and the lower animals. From a comparison of this passage with that relating to the same subject in Gen. ix. 1–4, it might be inferred that the writer of the former entertained the notion that before the flood not only man, but all the lower animals were destined by their Creator to live on vegetable food. Such an opinion it is impossible, in the face of the geological evidence to the contrary, to maintain for a moment. If, then, such an idea were beyond doubt involved in the passage, the only reasonable way of obviating the difficulty would be to suppose that it formed no part of the original narrative, but was subsequently inserted by a later hand, under the

guidance of an imaginative and imperfectly informed mind.

The form of expression, however, used in this passage, does not of necessity involve such an interpretation. The true explanation of the difficulty is to be found in the usage of the Hebrew writers, who not unfrequently employed general or universal terms in a restricted sense. The difficulty is the same as what occurs in reference to the supposed universality of the Noachian deluge. The Hebrew narrator of that event says that 'all the high hills under the whole heaven' were covered by the waters. But the discoveries of modern science make it plain that the whole heaven must be here understood to mean the whole visible horizon as viewed from the ark—not the whole heaven all round the globe. In like manner, with reference to the famine in the days of Joseph, it is affirmed that the famine was over all the face of the earth, and that all countries came into Egypt to Joseph to buy corn, because that the famine was so sore in all lands. But notwithstanding the universality of these expressions, they must obviously be taken in a very restricted sense, and can refer only to the group of countries in the neighbourhood of Egypt with which the Hebrews were acquainted.

The same principle of interpretation should be applied to the language contained in Gen. i. 29, 30. The terms 'every green herb,' 'every tree,' 'every beast,' are to be taken in a general, not an universal sense. It is not true that *every* herb bearing seed, and *every* tree in which is the fruit of a tree yielding seed, is fitted for human food; for the seeds of some herbs and the fruits of some trees are poisonous. So also *every* green herb is not fitted for the food of the lower animals, for some of them also are poisonous. In like manner the terms '*every* beast of the earth,' and '*every* fowl of the air,' and '*every* thing that creepeth upon the earth,' ought no more to be under-

stood universally than 'all countries' and 'all lands' in the case of the famine, or 'all the high hills, under the whole heaven,' in the case of the flood. The carnivorous animals are passed over in silence; but it may not be thence inferred that the writer of these words imagined all animals to have been at first restricted to vegetable food. A similar limitation is plainly necessary in the interpretation of the 19th and 20th verses of the 2nd chapter. The cattle, beasts, and birds there mentioned can have been only those with which the Caucasian race of mankind were acquainted. The animals peculiar to the American continent, the Indian Archipelago, and Australia cannot with any degree of probability be held as included, notwithstanding the universality of the expressions employed.

After giving the greatest possible weight to the arguments in favour of the theory of a divine revelation, and the least possible weight to the objections which may be urged against that view, there will still remain the question whether the revelation must be supposed to have been of necessity made in words, or simply by the infusion of ideas into the mind of the narrator. Now the verbal hypothesis would be more of an embarrassment than an advantage, while it would really add nothing to the authority of the narrative. Truth silently infused into the mind is quite as much truth as if it were embodied in words impressed on the physical ear; nor would it appear less veracious to the mind of the receiver. An original idea arising in the mind, we know not how, will often convince the understanding more readily and vividly than ideas received from without. Nor are words absent in the case of internal impression; for all original ideas, in the act of being conceived by the mind, naturally clothe themselves in words, seeing it is in words that the mind thinks. In the case before us it seems enough for

all practical purposes to suppose the language of the narrative to be simply the natural expression of conceptions wrought in the mind of the narrator, in virtue of a silent influence exerted on it by the omniscient mind of the Deity.

It ought ever to be kept in remembrance that it is impossible to prove the narrative to be true by merely assuming it to be divinely inspired. It is only possible to establish its divine authority by demonstrating its truth. The whole question is one not of faith, but of evidence, and a reasonable probability is all that can be reached. If any man feel dissatisfied with the proofs of the truth of the Hebrew narrative, he ought not to be charged with want of faith, for preferring the view that it is a mere human theory. For it must be allowed to be a serious thing to claim divine authority for any writing whatever, except upon evidence sufficient to satisfy not a superstitious and imaginative, but a reasonable, sober, and truth-loving mind.

NOTES.

Note A (Pages 56 and 58).

The brightness of the sun's surface was compared with that of incandescent lime, by experiments in which the lime was heated by the oxyhydrogen blow-pipe, from oxygen and coal-gas, to about 3,600° F., the temperature being estimated from the effects of the radiation on a black-bulb thermometer. It was found, by observation with a photometer, that at this heat the lime was nine times more luminous than had its surface been lighted by the sun's rays, his zenith distance being 31° 49′ 48″. Making allowance for the absorption of solar light by the atmosphere at this zenith distance, the incandescent lime would be only about six and a half times brighter than had it been illuminated by the sun at the outskirts of our atmosphere. But as at the immediate surface of the photosphere the sunlight is 46,000 times more concentrated than it becomes on reaching the earth's orbit, the primary brilliancy of the solar light will be about 7,000 times greater than that of the incandescent lime. Were the heating power at the immediate surface of the sun in the same proportion greater than that of the incandescent lime, it would be equivalent to 7,000 times 3,600° F., or 25,200,000° F. But it will be afterwards shown that the heating power at the immediate surface of the sun is probably not more than about 5,750,000 times what would be required to maintain a black-bulb thermometer at 1° F. above the temperature of the medium in which it might be placed. The heating power of the solar radiation is thus more than four times less, in proportion to its brightness, than is that of incandescent lime.

Note B (Page 69).

Let it be assumed that the sun's mean distance from the earth is, according to the value assigned to the parallax by M. Leverrier, 91,348,700 miles. The squares of the periodic times being proportional to the cubes of the mean distances, and the earth's periodic time being 31,588,150 seconds, it follows that the periodic time of a body at the distance of a million of miles from the sun would be 36,180 seconds, or 10h. 3m.; while that of a body at the distance of 700,000 miles would be 21,189 seconds, or 5h. 36m. 29s.

Note C (Page 78).

The sun's mean angular diameter being 32′ 3″·6, and his estimated distance 91,348,700, his linear diameter will be 851,840 miles. An angular projection of about a second is the least that can be discerned with such magnifying powers as can be applied to the sun. This corresponds to a linear projection of about 440 miles.

Note D (Page 85).

The only way of arriving at an idea of the force which is brought into play in the case of the luminous vibrations of the ether, is by comparing it with that which operates in the case of those vibrations in the air which produce the sensation of sound. The highest note audible to the human ear corresponds to about 8,200 vibrations in a second, the lowest to about sixteen. Sound travels through the air at the rate of 1,090 feet in a second; so that in length the shortest sonorous wave is about 1·5951 inch, and the longest about 817·5 inches—the proportion being as 1 to 512·5.

The force by which any disturbed particle is restored to its point of rest is equivalent to that which would move it through its greatest amount of departure from that point, in the fourth part of the period of vibration. If the force be uniform and the same for all the waves of different lengths, the ratios which the wave-lengths bear to the excursion of each particle comprehended in the wave will be in inverse proportion to the ratios which the wave-lengths bear to each other. The longer the wave the

smaller will be the proportion which the wave-length bears to the individual excursion. Thus, in the above case, the ratio which the shortest wave-length bears to the excursion of each particle comprehended in it will be to the ratio which the longest wave-length bears to the excursion of each particle that it comprehends as 512·5 to 1. Again, if the force be doubled, the proportion which each wave-length bears to the excursion of its individual particles will be halved.

For the purpose of this comparison, let it be assumed that the force is uniform, and the same for waves of every length in the same medium. In the case of the air let the average intensity of this force be supposed equal to that of terrestrial gravitation, which draws a particle through 193 inches in the first second. Seeing that the spaces are proportional to the squares of the times, in the sixty-fourth part of a second, which is the fourth part of the period of the longest sonorous vibration, this force would drag a particle through 0·047119 parts of an inch. To this excursion the longest sonorous wave-length (817·5 inches) is in the proportion of 17,349 to 1. In the 32,800th part of a second, which is the fourth part of the period of the shortest sonorous vibration, the same force would drag a particle through one 5,574,300th part of an inch. To this excursion the shortest sonorous wave-length (1·5951 inches) is in the proportion of 8,891,600 to 1. Now 8,891,600 is to 17,349 as 512·5 to 1, the inverse proportion of the wave-lengths themselves.

This same law will of course hold in the case of the ethereal waves as compared with each other, but not as between the luminous and sonorous waves; because these exist in different media, and the forces by which the particles are urged home to their points of rest are also very diverse. These forces are proportional to the squares of the velocities with which the wave-motion travels in the different media. Although the actual speed with which sound travels in air is 1,090 feet in a second, this rate is partly attributable to a certain change in the elasticity of the air, accompanying the movements of its particles. Save for this circumstance, the rate would be only 916 feet in a second. As there can be nothing corresponding to this change of elasticity in the case of the free ether, it is needful for the purpose of this comparison to leave its effects out of view, and to take the velocity of sound at the lower estimate, which is due to air of

unvarying elasticity. As light travels about 185,000 miles in a second, its speed exceeds that of sound 1,066,375 times. The square of this quantity represents the number of times that the elastic force of the ether exceeds that of the air. It is in round numbers 1,137,156 millions of times.

Taking the longest luminous wave-length at thirty, and the shortest at fifteen millionths of an inch, being in the proportion of two to one, the number of vibrations corresponding to the former is 390,720 thousand millions, and to the latter 781,440 thousand millions in a second. In the fourth part of the minute fragment of time corresponding to a single vibration of the longest wave, a force 1,137,156 million times more intense than terrestrial gravitation would drag a particle through a space equal to one 333,880th part of the millionth of the wave-length. So also, in the fourth part of the time corresponding to a single vibration of the shortest wave, the same force would drag a particle through a space equal to one 667,760th part of the millionth of that wave-length—these two ratios being again as one to two, the inverse proportion of the wave-lengths themselves.

The force here brought into play, being that by which the ethereal particles are either retained in their points of rest or restored to them when disturbed, must be inherent in those particles themselves, and must accordingly be constant for the free ethereal medium. Its intensity is manifested in the amazing rapidity of the motion produced, a rapidity enhanced by the smallness of the spaces through which the particles are moved.

Note E (Page 92).

A communication on this subject appeared in 'The Engineer' of October 22, 1869, of which the following is the substance. Let it be assumed that the luminiferous ether consists of two fluids X and Y, and that X is less repellent towards iodine than towards silver, while Y is the contrary; that in each molecule of iodide of silver, composed of an ultimate of iodine and an ultimate of silver, these two ultimates will be very near each other, but not in absolute contact; that there will be between them a minute interval occupied by the ether, not, however, in its usual

condition of an intimate mixture of X and Y, but with X accumulated next the iodine ultimate, and Y next the silver ultimate; and lastly, that in the wider intervals between the molecules of iodide of silver the ether will be in its normal condition.

In the dark, and at moderate temperatures, the molecules of iodide of silver will vibrate gently to and fro, urged by those slow invisible undulations of the ether in their interstices which cause temperature. But on exposure to light a double result will ensue. A large portion of the molecules will begin to vibrate in unison with the yellow undulations, producing the primrose tint of the salt. But by the quicker actinic undulations there will be set up a vibratory condition of the ultimates of iodine and silver constituting each molecule of the compound. Owing to the great proximity of the iodine ultimate to the silver ultimate, the vibrations between them can have but a very small intervening amplitude; consequently their natural state of vibration must be extremely rapid. Hence their vibrations can be synchronous only with the more rapid luminous vibrations at the violet end of the spectrum; so that it is only these last that can originate the minute vibrations between the iodine and the silver ultimates. But these, once established, may be sympathetically prolonged by undulations double their length and half their period, as are those at the extreme red end of the spectrum. Thus, suppose the ultimates of iodine and silver each to vibrate, under the stimulus of the violet waves, at the rate of 800 billion times in a second, every alternate vibration might receive a fresh impulse from luminous vibrations at the rate of 400 billions in a second. This consideration explains why it is that the red waves, although unable to establish the actinic condition, are yet able to continue it after it has once been commenced by the action of the violet waves.

Confining attention, then, to these minute rapid vibrations of each ultimate of iodine and silver opposed the one to the other, it is obvious that their alternate approach and retreat must promote the intermixture of the X and Y fluids in the intervals between them, until it become complete. The mere vibratory motion alone would not weaken the attraction of the iodine for the silver; but the intermixture of X with Y will; because neither the iodine nor the silver has any longer next to it the fluid for which each has respectively the least repulsion. This

weakening of the attraction, however, does not in this case go so far as to disengage the iodine from the silver.

These effects being kept in view, two cases of actinic action present themselves for explanation—that of the moist, and that of the dry collodion film, charged with iodide of silver. In the moist film the vibratory action between the ultimates of iodine and silver may be supposed to continue for a considerable time after the stimulus of the light is removed, like the thermal vibrations of a body which is slowly cooling. When the developer is applied during the subsistence of these after-vibrations, and while the X and Y fluids continue intermingled, its action will be promoted by the motion; because at alternate intervals the attraction between the iodine and the silver is more weakened, and the moment of greatest weakness is seized by the developer to effect their separation. If the application of the developer be too long delayed, the motion becomes more and more languid, so that the X and Y fluids regain their state of separation, and all things return to the condition in which they were before the action of the light began. Hence the developer fails to effect the decomposition after a time.

In the dry collodion film, again, it is more difficult to establish the vibratory motion between the ultimates of iodine and silver, by reason of the rigidity of the film, a difficulty evidenced by the longer exposure to the action of light found requisite. For the same reason it is probable that the moment the action of the light ceases, the vibrations are stopped. Now the general tendency of the vibrations has been to widen the interval between the iodine and silver ultimates, by promoting the intermixture of the X and Y ethereal fluids, so increasing their repulsive energy in relation to both ultimates. Hence when the vibrations suddenly cease, a large number of the ultimates will be arrested while their separation is greater than what it was before the light began to act. This condition of increased separation may be preserved for a long time, owing to the hindrance to motion presented by the dryness and rigidity of the film. Hence it is that in the case of the dry film the developer will act at a long interval after the exposure to light. The attraction between the iodine and the silver has been permanently weakened, owing to their ultimates having been arrested in positions farther asunder than they are in the normal iodide of silver.

The action of ozone, in preventing the decomposition of the iodide of silver by means of a developer after exposure to light, is probably chemical, the ozone uniting with the iodine to retain the silver with a force too powerful for the developer to overcome. The prolonged action of ozone might nevertheless separate part of the silver in the form of oxide, as probably happens in the experiments of M. Niépce, in which ozone appears to exert on salts of silver an action similar to that of light.

Should the hypothesis of there being two fluids constituting the luminiferous ether find general acceptance, that which tends to accumulate near the ultimates of iodine, chlorine, &c., might be called pariodine, while that which tends to accumulate near the ultimates of silver might be named parargyrine.

Note F (Page 94).

The nature of the radiation sometimes alters the character of the effect produced by the medium. When the radiation consists wholly of slow vibrations, and is therefore insensible to the eye, it will be more powerfully absorbed by one body A, than by another body B. But if the radiation consist both of slow and quick vibrations sensible to the eye, these two bodies may change places, and the body B become the more absorbent of the two. Formic ether and sulphuric ether furnish an example of this interchange, as do also in certain cases chloroform and bisulphide of carbon.

Note G (Page 99).

The Roman observations by Father Secchi establish the remarkable fact, that the excess of sun over shade temperature at the earth's surface is almost entirely independent of the season of the year, being nearly as great in midwinter as in midsummer; the fluctuations, however, being greater in the latter season. This result is the more surprising when it is considered that the atmospheric tract through which the sun's rays have to pass is very much longer in winter than in summer. The fact, indeed, would be inexplicable, save for the light thrown upon it by Professor Tyndall's experiments, which prove the absorption of the atmosphere to depend almost entirely on the amount of

moisture it contains. This amount is greatest in summer, least in winter, and the adjustment is so nice that the sun's rays traverse nearly the same mass of watery vapour at both seasons, the longer tract in winter containing no more vapour than the shorter tract in summer. It thus arises that in temperate climates, where the amount of suspended moisture varies the least, the excess of sun over shade temperature oscillates between 19° and 25° F., and attains a general mean amount of about 22° F. for both summer and winter. Although in tropical climates the fluctuations are much greater, there is no reason to suppose that, except in particular localities, there is any considerable departure from this mean. This estimate applies to the hour between 11 A.M. and noon, the period of the day when the excess of sun over shade temperature is greatest, the maximum being generally attained at about 11 o'clock. Observations made in England give similar results.

At different periods of the same day the absorption of the solar radiation by the atmosphere varies exceedingly; but it is always greater at any given distance of time after 11 A.M. than it is at the same distance before that hour; because the amount of moisture in the air increases as the day advances, so that the absorption is greatest at sunset. The excess of sun over shade temperature is then only about 10° or 12° F. at the sea level.

Dr. Hooker's observations are of great value, as showing the effects of height in augmenting the excess of sun over shade temperature, by decreasing the amount of moisture through which the radiation has to pass. They were taken at various heights from near the level of the sea up to 18,000 feet. He found that at heights between 7,000 and 8,000 feet the mean excess of sun over shade temperature is increased to about 67° F., or 45° above the mean at the sea level. This difference is due to the absorption exerted by the moisture contained in the intervening column of air.

The observations made by Mr. Glaisher, during his balloon ascents, are also useful as showing the influence of the humidity of the air on its temperature. He found that at considerable heights the air is frequently warmer than it is at more moderate elevations, by reason of its containing a greater amount of moisture. He also ascertained that in the atmosphere over England the humidity diminishes very rapidly above 18,000

feet, and at the height of five miles becomes inappreciable. It hence follows that all that portion of the atmosphere which exists above five miles exerts little or no absorptive action on the sun's rays. This limit of absolute dryness is higher in warm than in cold countries, in summer than in winter; and the variation in the height of this limit tends greatly to equalize the power of the solar rays at the sea level.

From the Himalayan observations it appears that the mean amount of moisture in the air at the sea level in England, namely three grains to the cubic foot, is attained at a height of about two miles in the Himalayan district; whence it may be fairly inferred that the limit of absolute dryness is there two miles higher than it is in England, so placing it at a height of about seven miles.

From an analysis of Dr. Hooker's observations, it appears that the amount of moisture suspended over a square foot of surface in a column of air 18,000 feet in height, in the Himalayan district, is about 9·3 lbs.; and if the same law of distribution prevail up to the limit of absolute dryness, the total weight on each square foot will be about 12·2 lbs., or nearly 0·565 per cent. of the weight of the air resting on the same surface. Of this mass of moisture about 5·4 lbs. suffice for the absorption of the 45° of the solar radiation before mentioned. Hence the total of 12·2 lbs. will absorb about 102° F. This weight of aqueous vapour will absorb the same amount of heat, whatever be the length of the column of air through which it is diffused; but the temperature acquired by the air will be in inverse proportion to the length of the column. The excess of sun over shade temperature, at the surface of the earth, being in temperate climates nearly the same in winter as in summer, it follows that in the former season the 12 lbs. of watery vapour must be distributed over a much longer atmospheric tract, through which the rays pass obliquely; consequently the limit of absolute dryness must be at a much lower level in winter than in summer. If to the mean excess of 22° F. of sun over shade temperature at the sea level be added the 102° absorbed by the moist air of the atmosphere, and another 1° for what may be absorbed by the dry air occupying the higher regions, we obtain a total of 125° F. as the probable excess of sun over shade temperature at the outskirts of the atmosphere.

As regards experiments with melting ice, it is on those of Sir

John Herschel and M. Pouillet that the greatest reliance is placed. Vertical sunshine at the sea level was found to be capable of melting in a minute, according to the former observer 0·00752, and according to the latter 0·00728 parts of a cubic inch of ice. It is easy to find, by calculation from these data, the amount of heat which vertical sunshine, received on a square foot of blackened surface, would impart to 1 lb. of water in the first second of time. The greater result gives for this temperature 0°·0862 F., the less 0°·0834 F.

In reference to his experiment, Sir John Herschel estimated the atmospherical absorption at 50 per cent. This would make the solar radiation at the outskirts of the atmosphere capable of imparting to 1 lb. of water per square foot of surface 0°·1724 F. in the first second of time.

M. Pouillet, in reference to his experiment, estimated the atmospherical absorption at only 25 per cent. This would make the power of the sun, at the outskirts of the atmosphere, capable of imparting to 1 lb. of water, per square foot of surface, only 0°·1112 F. in the first second of time.

Experiments made with a black-bulb thermometer, containing seventy-two grains of mercury, and exposing to the sun a semi-surface of 0·343 parts of a square inch, showed that, with an excess of sun over shade temperature amounting to 25° F., the rise in the first two minutes of exposure was 16°·1. According to the ascertained rate of progression for the instrument, this corresponds to a rise of 0°·2144 in the first second of time. Hence 125° of excess of sun over shade temperature would produce in the first second a rise in this instrument of 1°·072. Taking into account the difference between mercury and water, as respects their specific heat, this rise would be equivalent to 0°·1544 F. communicated to 1 lb. of water per square foot of surface in the first second of time.

This result shows that, according to these observations and those of Dr. Hooker and Father Secchi, the estimate of the atmospherical absorption made for his experiment by Sir John Herschel is too high, while that made for his by M. Pouillet is too low. In both instances, however, the actual absorption must have been much below the mean rate for temperate climates: consequently the excess of sun over shade temperature must have been far greater. The highest excess of sun over shade tem-

perature actually observed by Dr. Hooker was 94° F., which he found on one occasion (December 27) at the height of about 10,000 feet. This corresponds to about 0°·117 imparted to 1lb. of water in the first second, and is accordingly higher than the estimate of M. Pouillet for the full effects of sunshine at the outskirts of the atmosphere. But as there must have been, even in midwinter, a considerable amount of absorptive atmosphere above the height of 10,000 feet, this observation proves the estimate of M. Pouillet to be too low. On the other hand, as the amount of moisture contained in the atmosphere of the Himalayan district is rather over than under the mean, the amount of absorption as calculated from it can scarcely be too low, and it is thus improbable that Sir John Herschel's higher estimate can be correct.

Taking the whole observations into account, then, it appears to be, in the present state of our knowledge, fair to estimate the power of the solar radiation, at the outskirts of the atmosphere, as being capable of communicating to 1lb. of water, in the first second of time, 0°·1544 F., or 0°·0086 C. per square foot of blackened surface, and as being able to maintain a black-bulb thermometer at 125° F. above the point it would mark in the shade.

Note H (Page 101).

To show that no known substance could retain the liquid or solid form when subjected to such a heat as that at the surface of the sun, we may take for example such refractory substances as iron, platinum, and palladium. The dilatation of these bodies for 180° F., the difference between the freezing and boiling points of water, is 0·0014, 0·0009, and 0·001; so that for 5,750,000° F. the dilatation would be nearly 45, 29, and 32 times their respective volumes. But we know of no solid capable of withstanding such a dilatation, without first passing into the vaporous condition which the above-named bodies would assume on being expanded to a much more moderate extent. When a substance is once thrown into vapour, however, the law of its dilatation becomes straightway altered, and it expands according to the law which prevails among gases, namely 0·3663 parts for every 180° F. On attaining the vaporous condition, the dilatation which the above-

named refractory substances would attain would accordingly very considerably exceed the amounts above specified.

Note I (Page 121).

The estimate given at page 121 of the mechanical power of the solar radiation is found thus:—The radiation being capable of imparting to 1lb. of water 0°·1544 F. per square foot of surface in the first second of time, this quantity must be multiplied by the number of square feet in the surface of a sphere having a diameter equal to that of the earth's orbit. For this purpose the lower estimate of the sun's distance, namely 91,348,700 miles, may be assumed, as giving the most moderate view. This makes the surface of the sphere in square feet 2,923,400 trillions. Hence the solar radiation would communicate, in the first second of time, 1° F. to 451,366 trillions of lbs. of water, forming a spherical shell having a diameter equal to that of the earth's orbit.

The mechanical equivalent of heat being 772lbs. raised a foot high for every 1° F. imparted to 1lb. of water, the mechanical force exerted by the solar radiation in a second would raise 348,455 thousand trillions of lbs. a foot high.

The weight of our globe is uncertain, owing to the difficulty of determining its specific gravity, of which various estimates have been given—the lowest being 4·39, the highest 6·55. This last, which is that of Mr. Airy, the Astronomer Royal, may be assumed for the present purpose. It gives for the weight of the earth 15,650,944 trillions of lbs. Hence the solar radiation would be capable of raising more than twenty-two times the weight of our globe a foot high in a second.

Note J (Page 122).

As determined by various observers, the combustion of 1lb. of carbon in oxygen generates a force capable of raising 11,120,000 lbs. a foot high; so that it would require about 33,133,600 billions of lbs. of carbon to supply the motive energy emanating from the sun for a single second, and a mass of carbon equal in weight to our globe would afford a supply for less than six

days. The sun's diameter being as before assumed at 851,840 miles, and the force of gravity at his surface being to that which prevails at the surface of the earth as 28·61 to 1, the mass of the sun will be 331,297 times that of the earth. Now were the sun composed of nothing but carbon, and the requisite amount of oxygen for its combustion, these elements would exist in the proportion of six parts of the former to sixteen parts of the latter by weight; so that the carbon would be 90,354 times the mass of the earth. The supply of energy capable of being furnished by such a source would accordingly be exhausted in 1430 years.

Note K (Page 122).

Suppose a meteor, weighing a terrestrial pound, to retain its progressive motion while circulating close to the sun. It would there have its weight increased to 28·61lbs., and the force of its progressive motion would be the same as would be required to raise it through half the sun's radius, namely 1,124,422,000 feet. The mechanical value of each terrestrial pound of meteoric matter falling into the sun would therefore be 32,169,700,000lbs. raised a foot high. It would accordingly require about 10,832 billions of lbs. to fall into the sun every second, to meet the present expenditure of energy. At this rate a quantity of meteors equal in mass to the earth falling successively into the sun would supply the requisite amount of force for a period of about forty-five years and three quarters.

Note L (Page 122).

Let it be imagined that, at some remote epoch in the past, the solar orb was merely a nucleus about equal in mass and bulk to the earth, and that all the rest of his substance was, at that time, in the form of loose meteoric bodies revolving round this nucleus within the orbit of Mercury. Suppose also that a slightly resisting, very rare gaseous medium extended to the farthest limits to which these bodies reached. Let it be further assumed that these meteors were so systematically arranged that they should fall successively into the nucleus, at such intervals of time as to preserve a constant mean in the amount of motive

energy thus supplied, and which should exactly compensate the mechanical value of the solar radiation at its present rate of emanation. The radius of the nucleus, at first 3,958 miles, would by the accession of a mass equal to half that of the earth be increased to about 4,530 miles, which may be halved for the measurement of the mechanical energy developed by the fall of the entire mass equal to that of the earth. This half radius would be 11,961,000 feet, through which the 15,650,914 trillions of lbs., equal to the weight of the earth, is supposed to be moved. These two quantities multiplied together give in foot pounds the amount of energy developed by the fall of the first series of meteors equal in mass to the earth. It would afford a supply sufficient to meet the expenditure of the solar radiation for a little over six days. We have thus the first and last terms of a progression, namely six days and forty-five years and three quarters. We have also the number of terms, 331,296. Now supposing the gradual increase in the periods to have taken place by a common difference, the sum of the series, or total period during which the meteoric masses may have been accumulating, would be between seven and eight millions of years, for the whole of which they would have maintained the radiation of the sun at its present rate of expenditure.

Note M (Page 123).

The mass of the planet Mercury is to that of our globe as 0·1654 to 1. Multiplying the mass of the earth in pounds by this fraction, as also by 28·61 for the increase of gravity at the surface of the sun, and by the number of feet in half the sun's radius, we obtain for the mechanical value of a ring of meteoric bodies, whose united mass is equal to that of the planet Mercury, 83,277 billions of trillions of pounds raised a foot high, or 238,988,000 times the equivalent of the solar radiation for a second. This supply would therefore last a little more than seven years and a half.

Note N (Page 123).

As the solar radiation, if wholly absorbed, could communicate 1° F. to 451,366 trillions of pounds of water in a second, it

would impart to a mass of water equal to the sun itself 1° F. in about 133 days. Supposing the sun, therefore, to have a specific heat equal to that of water, which is the highest known, the loss of heat sustained by his entire mass would amount to 180° F., or 100° C., in about sixty-five years and a half. Now such a loss of heat would involve a considerable diminution in the bulk of the solar orb, supposing it to shrink to the same extent as water does in cooling. That liquid would lose about one twenty-second part of its volume by cooling 180° F. Were the sun to shrink as much, his diameter would be shortened by about one sixty-fifth part. This would correspond to a loss of about twenty-nine seconds of angular diameter since the beginning of the present century, a quantity far too large to have escaped detection. But this view is much too favourable for the theory, because there is no probability that the sun has a specific heat so high as that of water; so that, were it in progress of cooling, and receiving no fresh supplies, it would in all likelihood lose 180° F. in much less time than sixty-five years. Again, as regards the loss of angular diameter corresponding to that diminution of temperature, it would probably be greater than the quantity above assigned. For the cooling would tell most on the outermost layers of the sphere, which being probably gaseous would shrink much more than does water.

As regards our own globe, again, from calculations based on the earliest recorded eclipse of the moon, it appears that the earth cannot have lost so much as one hundredth of a degree Fahr. during the last 2,580 years; while Professor Sir Wm. Thomson, from data furnished by observation and experiment, calculates that the loss cannot have exceeded 0° 002 F., or one-fifth of the above amount. Taking the view most favourable for the theory, namely that the sun's loss of heat is only 180° F. in sixty-five years, his loss in 2,580 years would be upwards of 7000° F. It has been already shown that the present power of the solar radiation is about 5,575,000 times greater than would be required to maintain a black-bulb thermometer at 1° F. above the temperature of the medium in which it might be placed, consequently 2,580 years ago it would, according to the cooling hypothesis, have been 5,582,000 times. Hence the loss of 7000° would be about one 800th part of the total heating power during that interval. Now at the surface of the earth's orbit the power of

the radiation is at present capable of maintaining a black-bulb thermometer at 125° above the temperature of the medium in which it is placed. Supposing it to have sustained a loss of one 800th part, it would 2,580 years ago have been 125°·156. The diminution in the amount of heat continuously received from the sun by the earth during that epoch would accordingly have amounted to 0°·156 F., which is seventy-eight times greater than the loss of heat that the earth can be proved to have sustained.

It is thus evident that the meteoric theory cannot dispense with the continuous accession of meteoric matter, to supply the constant waste of motive energy attendant on the solar radiation. There is a great difference, however, between the increase of bulk due to a given accession of mechanical energy by the falling in of meteors, and the diminution of bulk which would attend a corresponding loss of energy by cooling. A mass of meteors equal to one and a half times the weight of the earth would supply the waste of energy involved in the solar radiation for about sixty-five years. Supposing such a mass to assume the same specific gravity as the sun, it would add to his bulk a quantity equal to about five and a half times that of the earth. This, however, would be less than one 220,000th part of the bulk of the sun; so that the addition thus made to his volume would be quite inappreciable in its effects on the sun's apparent diameter, and would be less than a 10,000th part of the probable diminution of volume which his orb would sustain by the loss of the same amount of motive energy by gradual cooling. It is conceivable that a certain amount of diminution in volume, from slow cooling, might coexist with a certain amount of increase from the accession of meteoric matter, and that these two might so balance each other as to preserve the apparent diameter of the sun constant for a long period of time. It is not its effect on the apparent size of the solar disc that exposes the meteoric theory to question; it is the absence of any evidence of the existence of a quantity of meteoric matter, between the sun and the orbit of Mercury, sufficient to maintain the requisite constancy of supply, not to speak of its inability to explain the phenomena of the willow-leaf shaped bodies, the faculæ, and the spots.

Note O (Page 124).

The power of the solar radiation at the earth's orbit has been shown to be capable of communicating to 1lb. of water $0^{\circ}\cdot1544$ F. per square foot of surface in the first second of time. At the rate of 772lbs. for each degree, this is equivalent to 119lbs. raised a foot high. The concentration at the solar surface being 46,000 times, the force there would be 5,475,000lbs. raised a foot high in a second, for each square foot of solar surface.

This great force, however, is the accumulation of all that is generated in a column having a base of a square foot, and half the thickness of the photosphere, allowing what may be generated in the other half to be propagated inwards. The probable length of such a column has been shown to be about 200 miles; so that it will embrace above a million of cubic feet. Thus the force generated in each cubic foot may be fairly estimated at about five and a half pounds raised a foot high in a second.

Note P (Page 129).

To illustrate the inadequacy of terrestrial organisms for self-support independently of sunshine, attention may be confined to a single square mile of terrestrial surface. The mechanical equivalent of the vertical sunshine received on such a space is 3,323 millions of pounds raised a foot high in a second. Under the most favourable circumstances, a square mile of terrestrial soil receiving this amount of sunshine, if planted with bananas, would yield, according to the estimate of Baron Humboldt, 50,000 tons of nutritious food yearly. This is the greatest amount of food-producing power of which the earth appears to be capable. But this quantity of food would suffice for only 100,000 men, whose united mechanical force would not raise more than ten millions of pounds a foot high in a second. It would therefore not be possible for any number of men, by their mere mechanical force, to produce anything like sufficient light and heat, in the absence of sunshine, to raise from the soil the food needful for their own support.

Note Q (Page 134).

It may perhaps have occurred to the minds of some readers to inquire whether it may not be possible to solve the very difficult problem of the origin of the sun's motive energy within itself, at least hypothetically. They might ask, Would it be transgressing the limits of legitimate analogy to imagine the Creator to have endowed living beings, inhabiting various organic structures, with the peculiar power of actually generating motive energy? Could such a faculty, conferred on a living being, be regarded as a greater specialty than is thought, or instinct, or the power of converting one kind of motive energy into another? The philosophical answer is, that such an idea could never attain to a higher level than that of a mere conjecture, incapable of proof save by mere inference from phenomena observed at an enormous distance, consequently open to misinterpretation. Nevertheless it must be allowed that such a hypothesis, could it be entertained, would go far to explain the manner in which the solar motive energy may be perpetually renewed from within that orb itself, as also how a portion of it may assume the radiant form of light, heat, and actinism; while it would then become a matter of indifference whether the motive energy were regarded as being generated in the photosphere or on the true surface of the sun, or partly in the one and partly in the other.

Our ignorance of any other agency but life, which appears capable of being applied to this purpose of originating motive energy, is the only justification for forming or entertaining such a conjecture. Were there no provision for this purpose, there would remain in the universe nothing save the mere conversion of one form of force into another, and that only by physical causes. But as the forces emanating from the sun are in a state of perpetual dissipation through the boundless ether, any vibratory force derived merely from the conversion of some other existing force incapable of renewal must ultimately cease. It is only life that has an inexhaustible source, namely the vital energy of the Creator; nor would there appear to be anything inconsistent with what we know of His modes of operation, in the hypothesis of His having constituted created life the ultimate source of that motive energy which comes to us in the form of solar radiation.

Such an idea, indeed, would at first sight appear to involve the necessity of supposing a continuous putting forth of the living energy of the Creator to be indispensable to the maintenance of the mechanism of the universe; nevertheless it is not necessary to suppose the repetition of any creative act to be involved in the continuous renewal of the solar energies. For if these have their origin either directly or remotely with living prime movers, such, once created, might have their existence perpetuated by processes of reproduction analogous to those subsisting on the earth. It is therefore only a conservative influence that it is needful to suppose the Deity to exert.

It is the opinion of our ablest physiologists, that the nervous energy of organic beings is either identical with electricity, or easily convertible into that force; so that, could we imagine organic beings to have been endowed with a power of generating their own nervous energy, such beings would constitute a never-failing fountain of electricity. Of the direct conversion of nervous power into electricity examples are afforded by the electric eel, the torpedo, and the mud-fish; while electricity is known to be convertible into heat, light, actinism, magnetism, or any other form of physical force. Of the direct conversion of nervous energy into light, again, we have examples in various luminous animals, from the microscopic organism which produces the phosphorescence of the ocean, to the brilliant fire-fly of South America. Of these last-named light-producers, an interesting account will be found in Mr. Hamlet Clark's 'Letters from Spain, Algeria, and Brazil,' pp. 149, 150.

It is remarkable that these organic lights present a continuous spectrum, uninterrupted by either dark or bright lines; in this respect resembling the light from an incandescent body. In some instances the light appears to be of the nature of electrical discharges; while in others there is reason to suspect its being produced by the direct action of certain organs, capable of producing a vibratory motion in the ether. Nor would this be at all wonderful, when it is considered that the substance of the optic nerve must be capable of vibrating with the same degrees of rapidity as those exhibited by the waves of the ether. For it is by the nerve's taking up these very rapid vibrations, and continuing to vibrate in unison with them, that the impression of brightness is produced; while in the case of subjective bright-

ness the nerve performs the same very rapid vibrations without external impression, but by internal excitement. It does not appear improbable, therefore, that in some of the luminous organisms this species of action may be reversed, and that nerves specially adapted for the purpose may be set vibrating, by the will of the living being, so rapidly as to excite in the ether corresponding vibrations of those several rates of rapidity which are requisite to produce the phenomena of luminous radiation and a continuous spectrum.

That organisms may exist in a medium of great rarity is evidenced by the fact mentioned by Dr. Hooker in his Himalayan journals, that when he was at an elevation of 18,000 feet, where the atmosphere is reduced to half its density, he observed kites and vultures soaring at a great height above him, and sustaining themselves in their peculiar hovering manner in that very rare medium, with apparently the same facility as near the surface of the ground. When it is remembered that our atmosphere contains only about 23 per cent. of oxygen, it will be perceived that an atmosphere of nearly pure oxygen between nine and ten times rarer than our own might suffice to sustain life. Such an atmosphere would convert only a very small proportion of luminous vibrations passing through it into heat.

The circumstance, however, that electricity and light, where they do manifest themselves in organisms, are simply conversions from pre-existing nervous energy, indicates that it is unnecessary to suppose either light or heat to be directly generated in these forms. They might in any case whatever, where they present themselves in the radiant condition, have derived their motive energy from nerve-force, which is capable of passing into all other forms of force. It is therefore unnecessary to imagine that in any of the great centres of motive energy the motion has its origin in either luminous or electrical organisms. Suppose our sun, for example, to have a solid nucleus of moderate dimensions, and to be surrounded by an atmosphere of immense height, were it possible to imagine organisms existing on the surface of the nucleus endowed with the power of generating their own nervous energy, that force might pass into the solar atmosphere, assuming the form of electricity, which would, according to the law which electricity always follows, accumulate in the uppermost regions. It might there be converted into light, in some manner analogous

to that in which the electricity of our own atmosphere is converted into light in the case of the aurora borealis. Its conversion into heat is also supposable; for if it once assume the radiant form, the vibratory motion, by being taken up by a gas or vapour well adapted for the purpose, would be thereby converted into heat, and given out again in the form of invisible radiant heat. Thus it is conceivable that one class of organisms might generate nerve-force, which, becoming converted into electricity, might ascend to the upper regions of the solar atmosphere, and there assuming the radiant condition, might partly go forth into the free ether, and partly return to the solar surface in the form of light and heat, in such moderate amount as might be beneficial, there to stimulate other organisms, which might, like our own vegetation, be capable of converting inorganic into organic matter, for the sustenance of those organisms which generate the nerve-force. Nor would the origination of nerve-force in this manner be at all more wonderful than are other functions of living beings, such as thought, instinct, volition, &c. He would be a bold man who should maintain that it is not in the power of the Creator to endow organic beings with the faculty of generating their own nervous energy, merely because He has not so endowed those which inhabit this globe.

It must be owned, however, that the existence of living organic prime-movers in the sun and fixed stars, as the ultimate sources of the motive energy emanating from those bodies, is an extreme supposition, resting only upon a somewhat imperfect analogy, seeing that, in all our experience, living organisms are capable only of converting one form of existing force into another. Nor would such a hypothesis be allowable, except in the absence of any more rational mode of explaining the origin of the motive energy given forth by the central luminaries of the universe. All that can be said in favour of this conjecture is that, were it admissible, it would adequately explain the origin of the motion, and might be defended, even in its details, by plausible arguments.

Note R (Page 368).

Instances have been cited by the supporters of the theory of derivation in which, as they maintain, there are evidences of the

actual passage of one species into another by means of a series of transitional forms. For example, Mr. Bates, in his work on the Amazons, vol. i., pp. 256–265, labours to prove the butterfly named *Heliconius Thelxiope* to have been derived from the more simple form *H. Melpomene*, giving examples of transitional forms between the two. But there is an utter want of evidence to show that these two butterflies, with all the transitional forms between them, may not be mere varieties of one and the same species, the forms named *Melpomene* and *Thelxiope* being the extreme variations. For the only reasons assigned by Mr. Bates for holding these two to be distinct species are, that he occasionally observed both butterflies living together in the same region without the intermixture of the transitional forms, and that he never saw them interbreed. But surely a point so theoretically important as this ought to be established by actual experiment, before concluding that it is impossible to obtain a fertile cross between these two butterflies, and so demonstrate that they are not only morphologically, but physiologically distinct species—more especially in face of the presumption raised by the intermediate forms in favour of their being merely extreme varieties.

Note S (Page 454).

It is not improbable that to *thohu* (תהו) may be traced the English adverb '*too*,' seeing it is applied to whatever is excessive. The Latin '*vae*,' the Greek '*ouai*,' and English '*woe*,' expressive of desolation or deprivation, seem all traceable to *vohu* (בהו). The Latin '*vapor*' appears to be compounded of '*vae*' and the Greek '*pyr*,' fire; thus involving the idea of the deprivation of weight by the action of fire. From this association of ideas it might be inferred that *vohu* implies a vaporous, weightless condition.

Note T (Page 456).

The apparent relation between the two words *thehom* (תהום) and *thohu* (תהו) is obvious in the original, the former differing from the latter only by the addition of the letter ם, corresponding to *m*. The other views are that *thehom* (תהום) is derived either from the verb *hama* (המה), 'to agitate,' or from *hûm* (הום), 'to

trouble.' But the circumstance that the word *hoshek* (חשך), 'darkness,' involves also the idea of 'stillness,' is adverse to either of these etymologies; while it favours the view of there being a connection between *thehom* and *thohu*. Possibly *thehom* may be the remote progenitor of the Scotch word *toom*, 'empty.'

Note U (Page 458).

The word *mayim* (מים) seems to reappear, with the sense 'fluid' involved in it, in the English word 'mum,' a beverage brewed from wheat. To the same source may perhaps be traced the Latin word 'mamma,' indicating the fountain of the nutrient fluid milk.

Note V (Page 459).

An idea has recently been suggested, that the moving of the Spirit of God on the face of the fluids should be understood as indicating that at this stage animal and vegetable organisms of the lowest types began to exist at the bottom of the sea. This incongruous notion, however, has been broached in forgetfulness that as yet, according to the narrative, the sea was not, neither was there an atmosphere to supply to the waters that absorbed oxygen so necessary to animal life. This hypothesis is, moreover, unsupported by any geological phenomena.

Note W (Page 460).

The word *or* (אור), 'light,' is probably the root of the Latin *uro*, 'I burn,' and its derivatives. The Greek πῦρ, *pyr*, 'fire,' may perhaps be traced to the same source. So also may the Latin *aurum*, 'gold,' and the English *ore*.

Note X (Page 463).

This same ערב, but pronounced *arev*, occurs in the original sense derived from the verb in Exod. xii. 38, where it is applied to a mixed multitude; and the name 'Arab' (ערב), from the same radical, was given to the inhabitants of the desert because they were a mongrel race.

Note Y (Page 467).

Some etymologists derive *shamayim* (שמים) from the verb *shom* (שום), 'to put or place,' thus making the noun to mean 'placers' or 'disposers.' They assign as a reason that the *shamayim* made a new disposition of the original *mayim*. Others again make the word a compound of *sham* (שם), 'there,' and *mayim* (מים); so that the meaning would be 'the fluids there,' in contradistinction to the fluids here. But neither of these two etymologies appears so probable as that given in the text. *Shamayim* would almost seem to reappear in Latin as *summum*.

Note Z (Page 491).

Nothing can more clearly indicate that the meaning of the Hebrew verb ברא, *bârâ*, is not 'to originate from nothing,' but simply 'to cause to be' indefinitely, without specifying the mode, than its employment in Genesis i. 27 to the formation of the human pair; while in the second chapter the verb יצר, *yâtsar*, is substituted, and such particulars are given as to prove the human organism to have been fabricated out of existing materials. It is this same verb *yâtsar* that occurs in Isaiah liv. 17, 'No weapon that is fabricated against thee shall prosper.'

Note A A (Page 497).

The Hebrew expression is ויסגר בשר תחתנה, *vayisegor bâsâr tahetennâh;* and on reference to 1 Kings vi. 6, it will be seen that this last word is applied to the nethermost chamber of the temple, so that 'underneath it' is quite a legitimate translation of this preposition.

Note B B (Page 498).

There are one or two other expressions in the narrative bearing on the nature of the process described. After stating that the Creator built the rib which He took from the man into a woman, it says, 'and He *brought* her to the man.' But the verb might be equally well translated, 'and He *joined* her to the man'—a

translation agreeing better with the idea of her having been formed from his side by some process either resembling gemmation or identically the same. Again, it is affirmed that Adam said, 'This *now* is bone of my bone and flesh of my flesh.' Although this be a fair interpretation, it is not the only one of which the language is capable. The word rendered 'now,' '*hafam*,'[1] is really a noun with the article. It means a stroke or pulsation, and it is only in a secondary way that it involves the idea of time. When such is the case it means an instant, the time occupied in making a sudden single stroke. Hence it occasionally means 'this instant,' or adverbially 'now.' But it quite as frequently occurs in the sense of a stroke, or pulsation renewed at regular intervals. If we so understand it here, reading 'And Adam said, This pulsation is bone of my bone and flesh of my flesh,' it might be conjectured that he felt the heart of the infant female beating against his side at the moment of his making the exclamation. His using the words 'flesh of my flesh,' as well as 'bone of my bone,' and his saying that she should be called woman because she was taken out of the man, while much against the notion of a mere rib's having been extracted from Adam and then miraculously metamorphosed into a full-sized woman by the addition of fresh extraneous materials, implies that the entire substance of the woman, bone and flesh, was formed from the bone and flesh of the man. This phraseology would be best explained by supposing her to have been formed by some process resembling gemmation from his side, and one of his ribs to have been absorbed in the process; for only in some such way could she be said to have been wholly taken out of the man.

This view would of course involve the idea of the infant female's having been nursed by the male. But there is little difficulty attending this part of the supposition, seeing there are two well-authenticated instances cited by Humboldt in which infants were suckled by their fathers.

The smallness of the probability attached to these conjectures cannot be regarded as an argument in favour of the still more highly improbable notion that the Deity, assuming a human form, subjected Adam to a surgical operation, extracted one of his ribs, and miraculously metamorphosed it into a full-sized woman. It is merely an additional reason for regarding the narrative as an allegory or parable.

[1] הפעם

MEMORANDUM.

THE INTERVAL between the printing of the foregoing work and the completion of the engravings, has been employed in studying M. Ångström's work on the normal solar spectrum, and measurements of the wave-lengths corresponding to the principal fixed lines, with relative atlas. This study has revealed the following relations.

M. Ångström gave most attention to the double line E, and from the mean of numerous observations he states the wave-length of the more refrangible E to be in ten millionths of a millimeter 5268·67, or in hundredths of the millionth of an inch 2075·7.

Adopting this value as correct, and assuming $E = 10$, the relative values of the other seven wave-lengths may be found by the following equations:—

(a)	$2A^2 - 6A$	$= 3E^2 + 3E.$
(b)	$(6A^2 - A) - (6B^2 + 2B)$ . .	$= E^2 + 9E.$
(c)	$(4B^2 + 2B) - (4C^2 - 2C)$ . .	$= E^2 + E.$
(d)	$(6C^2 - C) - (6D^2 + 6D)$ . .	$= E^2.$
(f)	$C^2 + (2F^2 - 6F)$	$= 2E^2 + 7E.$
(g)	$(4G^2 + 4G) - (C^2 + 2C)$ . . .	$= E^2 + 2E.$
(h)	$(2F^2 + 6F) - (H^2 + 4H)$ . .	$= E^2 + 4E.$

These seven give rise to the following more general equation, embracing all the wave-lengths.

$$a + b + c = d + f + g + h = 6E^2 + 3E.$$

This equation proves each wave-length to be dependent

on all the others, and *vice versâ*. It is the longer of the two D waves, and the shorter of the two H waves, that enter into these formulæ.

The relative values of the eight wave-lengths, as given by observation and as calculated from the foregoing equations, are as follows :—

	Observed	Calculated	Differences +	Differences −
A	14·432490.	14·432517.	0·000027	
B	13·033840.	13·033839.		0·000001
C	12·454950.	12·454930.		0·000020
D	11·189030.	11·189003.		0·000027
E	10.			
F	9·225744.	9·225760.	0·000016	
G	8·175214.	8·175183.		0·000031
H	7·464880.	7·464871.		0·000009

These trifling differences are much within the limits of probable errors of observation, the greatest of them corresponding to less than two thousandths of the millionth of a millimeter.

DESCRIPTIONS OF PLATES.

DESCRIPTION OF PLATE A.

The objects represented in this plate are all shells of the Foraminifera, recent and fossil. The simplest of these shells consist of a single chamber, with one principal opening, and sometimes with numerous other more minute holes (Nos. 2, 3, 4, 5, 6, and 21.) In some genera the shell consists of several chambers, arranged in a single straight, or simply curved line (Nos. 10, 11, 12, 16, 17, 48.) In other cases, the chambers are wound around one or more axes, forming various convolutions, and for the most part arranged in a spiral. The greater number of the specimens represented in the plate are of these sorts. In some instances each chamber invests half the entire circumference (No. 52); while in others the chambers are tubular, and radiate in all directions from a centre (No. 54).

The foraminiferous shells of the spiral form bear a remarkable resemblance to those of the Ammonite, the Nautilus, and other highly organized Cephalopods, from which the animals differ widely, in respect of the simplicity of their organization. See in particular Nos. 8, 14, 23, 24, 27, 43. Others present a striking likeness to works of art, as for instance Nos. 2, 3, 4, 10, 11, 48.

Most of the forms shown in the plate are from recent specimens found in deep sea soundings, made in different quarters of the world; but others, as Nos. 57, 58, and 59, are fossil, and from the oolitic limestone. This rock is almost entirely composed of foraminiferous shells or their fragments, embedded in a calcareous paste. Among these are many forms exactly resembling those of existing species; but they are generally so crowded, and are so seldom lying in a good position, that it is difficult to draw them. It is for this reason that recent specimens have been preferred.

The great bulk of the specimens represented in the plate are drawn to the scale of 50 diameters; but Nos. 11, 33, and 60 are magnified to 100 diameters, Nos. 58 and 59 to 25 diameters, and No. 57 to only twelve diameters.

DESCRIPTION OF PLATES B, C, D, E, F, & G.

The whole of the objects represented in these six plates, with the exception of Nos. 86, 87, 88, 89, and 94, are shells or parts of shells of the Polycystina. The only recent specimen is No. 65, which was found among Foraminifera, taken from the depth of 2000 fathoms in the Atlantic. All the others are fossil and from Barbadoes.

As in the case of the Foraminifera, some of the forms of the polycystinous shells are similar to those of animals much higher in the zoological scale (Nos. 36, 68, 74). The resemblance to works of art is still more striking and frequent in the Polycystina than in the Foraminifera. See in particular Nos. 29, 53, 54, 69, 73, 75, 76, 79, 81, 84, 85, 92.

A peculiar feature of the Polycystina, and one which distinguishes them from the Foraminifera, is the frequent occurrence of horn-like projections—sometimes crowning the summit, sometimes placed at the base of the shell. In this latter case they are generally three in number, and appear to have been intended to support the shell in an upright position. Several of these tripods are represented in plate B. In some cases these supports are nearly straight (No. 19); in others curved inwards (Nos. 1, 2, 4, 5, 6, 7, 18 &c.); or outwards (Nos. 3, 17); while in a few instances they present a curve of double flexure like the leg of a modern chair (Nos. 8, 9). In one example, both the three supporting legs and the horn at the top are beautifully branched, like a deer's antler (No. 20). In other cases this ramification is confined to the upper horn (Nos. 43, 44, 51). In several instances the lower processes acting as points of support are numerous (Nos. 2, 12, 44, 46): and here also we have both the inward and outward curvature.

The processes are in some cases only two, placed at opposite sides or ends of the shell (Nos. 23, 26, 27, 32, 33, 34, 37). There are sometimes three lying in the same plane, like rays proceeding from a central circular disc (Nos. 80, 104). In some cases there are four, forming a cross (No. 28), while in other instances this form of a cross is assumed by the perforated shell itself, each arm being furnished with a process (Nos. 29, 30). In certain specimens, these processes, proceeding from the arms of the cross, are branched. The species (No. 24) is remarkable for the number and length of its spikes, and the irregularity of their arrangement. In several genera the size of the processes bears a very large proportion to that of the perforated shells. In most cases the processes are pointed at the end; but in a few instances they are blunt, or knobbed, or recurved (Nos. 22, 30, 37, 104). In one beautiful genus there are two spherical perforated shells,

united on one side by an arch, and on the other by two processes inclined to each other at an angle, and joined together by a cross piece (No. 25). This form would almost appear to be a combination of two similar to No. 37.

The manner in which the processes are inserted into the shell is curious. The shell (No. 27) is so transparent that, by shifting the focus of the microscope, this mode of insertion can be plainly seen. It is represented in plate G, fig. 1. It will be perceived that the spike has a root, which must be firmly imbedded in the sarcode. Figs. 2 and 3 of plate G show two other spikes disengaged from their shells.

In some species the spikes degenerate into short spines like those of the Echinus (Nos. 68, 95). The shell is in many genera crowded with short sharp thorns (Nos. 48, 49, 80, 91); while in others the thorns are replaced by rounded papillæ (Nos. 7, 8, 14, 26). In a few genera we find that, instead of the usual tubular processes, the perforated shell is itself prolonged into a tube (Nos. 39, 40, 49).

The holes, which characterize all the shells of this tribe, vary in form, size and arrangement. The most common form is round, but sometimes it is hexagonal. In No. 83 we have both of these forms in the same specimen. The circle is occasionally replaced by an oval, and the hexagon by a rectangle or trapezium; but these modifications occur chiefly when the holes attain a large size (Nos. 54, 58, 62, 64, 92). In some species we find circular holes, while the divisions between them exhibit hexagonal ridges (Nos. 11, 13, 21, 41, 42, 57, 91, 97). The difference in the dimensions of the holes is very great, and that too in the same specimen (Nos. 5, 6, 17, 58, 62, 63, 64). In a good many genera there is one principle opening besides the perforations in the shell (Nos. 68, 70, 72, 74, and several others). The holes are in some instances so numerous, and the divisions between them so fine, as to produce a resemblance to lace. In these cases, the holes are usually hexagonal (Nos. 105, 115).

The perforations are generally arranged in straight lines, in circles, in squares or in quincunx. The partitions between them also exhibit a variety of patterns. When the holes are disposed in circles they sometimes present a curious arithmetical arrangement.

The most striking peculiarity of this tribe, however, is the amazing variety in the forms of the shells themselves—some of them being quite unique in the organic world. The simplest form is the sphere, or the spheroid, prolate or oblate, and either with or without processes (Nos. 68, 71, 90, 109, 113, 123). Sometimes the prolate spheroid is modified into a cylinder with rounded ends (No. 23). A very common form is the oblate spheroid much compressed. A considerable variety of these is shown in plate F. They are all represented as they appear by transmitted light, so as better to display their markings. It will be perceived that several of them have their margins projecting beyond the body of the spheroid. In Nos. 99, 110, 116,

124, this margin is beautifully scalloped. In Nos. 112, 119, it is finely perforated. No. 120 has a margin composed of beautiful feathery-like projections; while in Nos. 97, 101, 102, 118, the margin is toothed. No. 114 has twelve conical processes at regular intervals; and in No. 106, the spheroid is transformed into a heptagon, with a process at each of the seven angles. The minute specimen No. 104 has three processes with knobs at the end. In Nos. 98, 109, 111, 113, 123, we have compressed prolate spheroids. No. 109 is remarkable for the large oval opening at the top—its greater axis lying obliquely to that of the general figure. No. 111, presents a curious modification of this ovoidal form; and in No. 107 it is still further modified by re-entrant curves. In No. 100 we have as it were two spheroids blended together.

Some of these shells are constructed one within another, the outer being connected with the inner by processes. This structure is shown partially in No. 31; and in the large specimen No. 23, there are several of these interior shells.

It is curious to note the manner in which the spheroid passes into forms altogether unlike itself, and that in several directions. For example, we have first a small spheroid open at the lower end, where it is succeeded by one, and sometimes two much larger—the resulting appearance being that of domes piled one above another (Nos. 2, 3, 5, 6, 17, 21, 22). These forms, by further modification, pass into the vase shapes Nos. 69, 73, 75, 76, 77, 79, 81, 84, 85.

The most peculiar forms however are those represented in plate D, especially No. 60, which is perhaps unique in the organic world. Here we see an eight-sided pyramidal tower, with plane faces and straight edges—having on each face arched windows piled one above another, each window having nine round openings—while on the summit is placed an egg-shaped mass covered with fine siliceous hairs, and connected with the main body of the tower by a narrow neck. This specimen presents a curious admixture of the forms peculiar to organic, with those which distinguish inorganic bodies. The plane faces and straight edges of the tower, sloping inwards towards the summit, recall some of the pyramidal forms found in crystallization. But in the egg-shaped body at the top, in the arched recesses, and round holes of the windows, we have a recurrence of the curved outlines characteristic of organic shapes. Strange as this wonderful structure seems, it is nevertheless connected by transitional forms with others much more simple. On the one hand, we have in No. 59, the same sort of windows, but the plane faces and straight edges are replaced by curved faces and edges. In No. 62 the window-like recesses are replaced by large openings, which render the figure more like a fire-escape. In No. 58 we have similar large openings occurring in pairs, while the sides of the tower have in the lower part a concave curvature, which gradually becomes convex towards the top. In Nos. 63 and 64, we have a further simplification of the form,

No. 63 being remarkable for the hexagonal shape of the openings. From these two the passage becomes easy into the simple cone No. 65, which again swells out in No. 66 into a hemisphere, so establishing a connexion with the spheroidal forms.

A careful examination of the plates will enable the discerning eye to discover several other remarkable transitions; and doubtless had we at once placed before us the entire series of forms assumed by the polycystina, we should be enabled to discover that they are all linked together by transitional types.

It is remarkable that, although the animals inhabiting these shells are closely related to the Foraminifera, the shells formed by the latter are for the most part of a totally different character, as regards both substance and shape. The shells of the Polycystina are siliceous, those of the Foraminifera calcareous. Only in a few instances is there any approach to similarity of form between them—as in Nos. 2, and 3, of plate A, and Nos. 43, and 67 of plate D. But we do not find among Polycystina those spiral forms so prevalent among the Foraminifera, nor do the latter affect the turreted, domed or vase shapes characteristic of the former.

Nos. 86, 87, 88, 89 of plate E, are of sponge formation, also No. 94 probably but not certainly.

All the specimens given in the plates are drawn to the scale of 100 diameters, excepting Nos. 25 and 63, which are magnified one half more.

DESCRIPTION OF PLATES H, I, J, & K.

These four plates contain representations of some of the most interesting of the forms of diatomaceous shells. Their great diversity of outline is one of their most remarkable features, and it is with a view to illustrate difference of shape, rather than of mere markings, that the specimens have been selected.

Some of the genera, which are of an elongated form, have a keel or ridge running lengthwise along the centre of the valve, apparently for the purpose of adding to its strength. (Nos. 28, 30, 35, 37, 42, 44, 58.) The dark margin produced by the connecting zone is conspicuous in Nos. 37, 43, 48, 83, 84, 85. All the shells are more or less curved, so as to incase the inner cell. A frequent form is that of a circular disc like a watch-glass, for example No. 15, which is distinguished for the singularity and beauty of its markings. Others of these discs are ornamented with minute dots or rings variously arranged, in some cases irregularly, in others symmetrically. Some are disposed like the spokes of a wheel. In one species the dots are so arranged as to form a cross like that on a Spanish dollar. In another they are disposed spirally, so as to resemble the engine-turning on a watch-case. In one species, this peculiar arrangement is assumed by hexagonal meshes resembling lace. There are some discs in which the dots or rings, are replaced by fine straight parallel lines. In one species the circle is divided into ten compartments, and the lines are parallel to each other in the alternate divisions. In another species the parallel lines cross each other obliquely, so as to cover the surface with lozenge-shaped markings. This same arrangement also occurs, where the lines are segments of circles. In one species the whole surface is covered with parallel waved lines. In several cases the central pattern is surrounded by a border of quite a different character (Nos. 72, 75, 77, 81). There are also beautiful discs, abounding in guano, and in the mud of the Australian rivers, which exhibit the splendid accidental colours of thin plates—red shading into blue, yellow into green, and so on.

Another not unfrequent form is the ellipse, or oval (Nos. 1, 6, 8, 10, 31). The oval is often smaller at one end than at the other; (see No. 4, remarkable also for the beauty of its markings). Occasionally two circular or two oval ends are united by a central concave curve (Nos. 3, 30, 41, 48, 49). In No. 2 we have a sort of transitional form between that of No. 1 and No. 3; for while one side of the valve presents a continuous oval curvature, like that of No. 1, the other side exhibits a re-entrant interruption, similar to

that which characterises both sides of No. 3. The commencement of a similar modification of outline may be traced in No. 34, as compared with No. 33, of which it appears to be a malformed specimen. But it is not improbable that this malformation, perpetuated and heightened in the progeny, might establish a permanent variety with re-entrant curves. In another specimen, No. 5, where the general form is oval, the central curve and those of the two ends are convex, with a re-entrant curve intervening. A still greater complexity of curvature is presented in No. 13, in which there are convex and concave curves both on the sides and at the ends of the valve. The markings on this frustule are also peculiar.

In some of the oval forms the sides are much flattened, and sometimes are quite straight, while the ends are rounded (Nos. 28, 44); while in 35 and 37 re-entrant curves intervene between the flattened sides and curved ends. Such elongated forms appear almost rectangular when, instead of the centre of the valve, the connecting zone is turned towards the spectator. This latter is termed the front view, while the former is termed the side view. Indeed the whole of the diatomaceous shells present diverse aspects according as they are beheld in one or other of those directions. Of the nearly rectangular form we have an example in No 38, which is the front view of a frustule whose valves are elongated ovals.

No. 82 presents another modification of the elongated oval, one side of the valve being convex and the other concave in its curvature. In No. 63 we have a convex and a concave curve on both sides, the curves being not far from parallel throughout. No. 58 exhibits a similar convexity and concavity on both sides, but the curves converge from the centre towards the extremities. In No. 73 the outline is symmetrically waved on both sides. This waviness of outline attains in No. 78 an extreme development; while in No. 87 it is more gentle but unsymmetrical. In Nos. 54, 59, 60, 62, 66, 79, 83, 84, 85, 86, we have a series of forms, more or less elongated, which seem to pass into each other by gradations. No. 29 is one of a series of forms concave on the one side, and having a sinuous outline on the other—the sinuosities varying in number regularly from one up to six.

Reverting to the circular disc, it also undergoes a remarkable series of modifications. In No. 45 it is altered into a heptagon with convex sides, in 39 into a hexagon with straight sides and rounded angles, in 47 into a hexagon with concave sides and convex angles. In No. 53 the hexagon has its angles sharp and its sides straight. The disc becomes in Nos. 43 and 76 modified into a pentagon with concave sides and convex angles. In No. 46 the pentagon has convex sides, while the angles are sharp-pointed with small concave curves on either side of each. These angular projections are in No. 40 reduced to four, and are more rounded at the points; while in 36 the four angular projections are still more rounded, and the four sides are concave. This figure becomes in No. 56 further modified into nearly a square; the angles being rounded, and the sides slightly convex. In No.

50 the angular projections are reduced to three, the projections being considerably elongated with convex sides. The three projections become still more rounded in No. 52, and the intervening sides become concave. The projections are yet more extended in No. 32, the intervening sides continuing concave. In No. 51 the figure becomes almost an equilateral triangle, with very slightly convex sides and rounded angles. The markings both on 32 and 51 are hexagonal.

When these trigonal valves are united by their connecting zone, the figure of the frustule is a triangular prism, so that, seen with one of its three sides next the eye, it appears rectangular. But even the valves themselves exhibit a tendency to assume occasionally the rectangular form, and the frustule then becomes nearly cubical. In like manner the four-angled form No. 40 tends to pass into the five-angled form No. 46, and the four-angled form No. 36 into the five-angled form No. 43. Indeed, all Diatoms exhibit a tendency to changeableness of form; while their peculiar modes of multiplication and reproduction tend both to increase the number of individuals thus modified, and to perpetuate the modification.

Some of the valves, besides varying in their outline, are also diversely bent, as respects their constituent plates. Thus Nos. 22, 24, 25 and 26, are curved like a saddle, while 18, 20, and 21 have a double curvature in the valve plate. Some genera are furnished with thorns and spikes, similar to those found in the shells of the Polycystina, but to a smaller extent. See in particular Nos. 55, 61, 65, 67, 89, 97, 105, 106, 107, 108. The forms 95, 98, 99, 104 and 109, which are also all distinguished by this peculiarity, are by some authorities excluded from among the Diatomaceæ; but the grounds of this exclusion are by others disputed.

The shells of the Diatoms are not perforated, like those of the Polycystina, the markings upon them being produced by elevations rather than depressions on the siliceous surface. Some of these markings are very peculiar. For example, in No. 90 they resemble musical notation; in No. 111 they are like Persian writing; while in No. 113 they resemble the Roman letter C turned four different ways.

In some of the genera the frustules are single, while in others they are united together in various manners, of which several examples are given in plate K. In the greater number of instances, they unite to form straight chains, as in Nos. 93, 96, 100, 101, 102, 103, 110, 115, 116, 117. The chain is sometimes considerably bent, as in No. 114. When the individual frustules are wedge-shaped, they form either a simply curved chain, or one that describes a complete circle, and then folds over upon itself, as in Nos. 92 and 94, or else they assume a form exactly like a fan, as in No. 112. In other genera, the frustules are united corner to corner, giving the chain a zigzag form, as in No. 111. For the most part the individuals composing a chain are all alike; but in a few genera they differ considerably, as in No. 100. This peculiarity is connected with their mode of reproduction. Many

genera secrete a sort of mucus, which enables the frustules to adhere together, as in No. 112. In this genus and in some others, the mucus ramifies like the branches of a tree, giving the whole a much more plant-like appearance than the generality present. This mucus, however, is found only in recent specimens.

It is needless to enter into a more detailed description of these interesting objects. A simple inspection of the plates will serve to convey a sufficiently accurate general idea of the appearance they present under the microscope; although much of their beauty is of necessity lost in their representation. All the specimens are magnified 250 diameters.

DESCRIPTION OF PLATE O.

This plate is designed to illustrate the forms presented by the Pollen of plants. In by far the larger number of cases, the form of the cell is either spherical or spheroidal. But in some genera it is variously lobed, or otherwise modified from the spheroidal form. The outer skin is most frequently smooth, but is sometimes downy, as in No. 30, or hairy, No. 15, or thorny, and that to such an extent as to appear starry (Nos. 11, 16, 18, 28, 29, 36). The pollen of compound flowers has usually this starry appearance. In No. 27, the surface is covered with somewhat long papillæ. The lobed forms are apparently composed of spheroids aggregated together and symmetrically arranged, most frequently in trigons, of which various examples are given in the plate. Occasionally there are only two spheres joined together as in Nos. 32, 34; sometimes four spheres are combined into a tetrahedron (No. 9).

Some of the pine tribe have a peculiar pollen, in which a large spheroid has two smaller attached to it, as in No. 33. The pines are further remarkable for the superabundance of their pollen, which is so great that, in the neighbourhood of pine forests, the ground is often covered with it throughout many square miles. It is also sometimes wafted into the atmosphere, and precipitated in showers of rain. The most singular perhaps of all the pollens is that of the *Basella rubra*, which assumes the form of a cube with slightly curved faces—the sharp angles being replaced by small spherical protuberances (No. 38). Some forms may be regarded as transitional between the spheroidal and the lobed—the spheroid being marked by symmetrical ridges and furrows (Nos. 4, 22, 26, 31). It is common to find a prolate spheroid marked by a single furrow, as in No. 6. Occasionally the simple spheroid is furnished with a membranous zone or frill (Nos. 7, 12, 35, 45). The prolate spheroid is sometimes modified into a cylinder with rounded ends (Nos. 19, 41). More rarely half the spheroid is replaced by a cone (No. 20). The pollen of the Fuschia (No. 23), which is trigonal, presents a striking peculiarity. Owing to the length of the stamens, and the drooping position of the flowers, there would be danger of its being lost before it becomes fitted to perform its office. To prevent this mishap, it is enclosed in a network of silvery looking fibres.

There is a great range of difference among the pollens in point of size; but this difference has no relation to the size of the flower. No. 24 is one of the largest, No. 17 one of the smallest. Neither is there any strict correspondence between the aspect of the flower and that of the pollen. The

flowers, from which Nos. 24 and 44 are obtained, exhibit a strong resemblance, but the pollens are quite unlike. On the other hand, especially among the globular and spheroidal forms, the flowers may be wholly dissimilar in aspect, and wide apart in the general classification of plants, while their pollens may be scarcely distinguishable one from another. The pollens differ in colour almost as much as the petals of flowers; but their colour most frequently differs from that of the petals of the flowers in which they are found. A few of the forms assumed by pollen resemble those of certain species of Diatoms. Compare Nos. 23, 25, and 42 of the pollens with Nos. 50 and 52 of the Diatoms, and No. 11 of the pollens with No. 68 of the Diatoms.

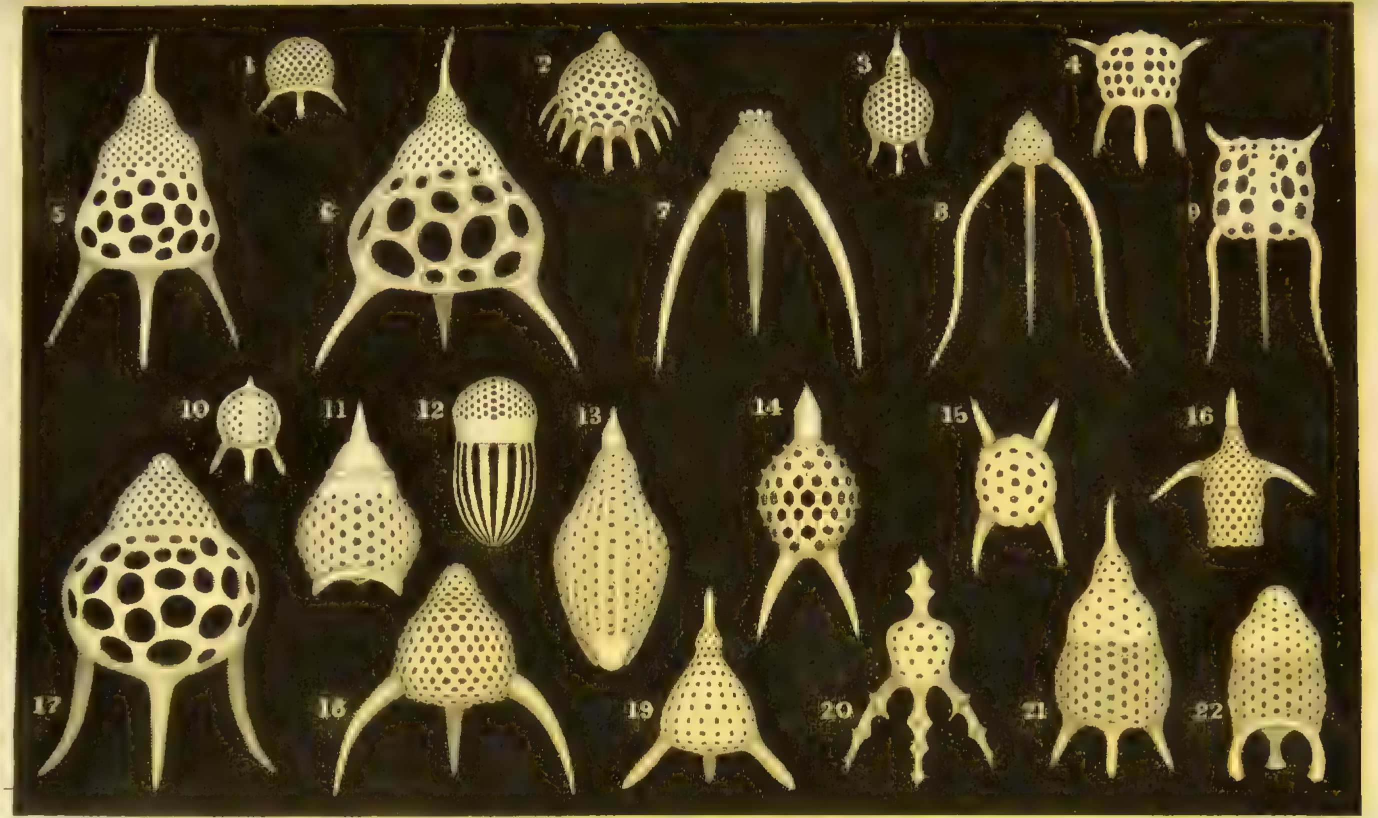
The following is a list of the plants whose pollens are represented in Plate O, magnified 250 diameters.

List of Pollen.

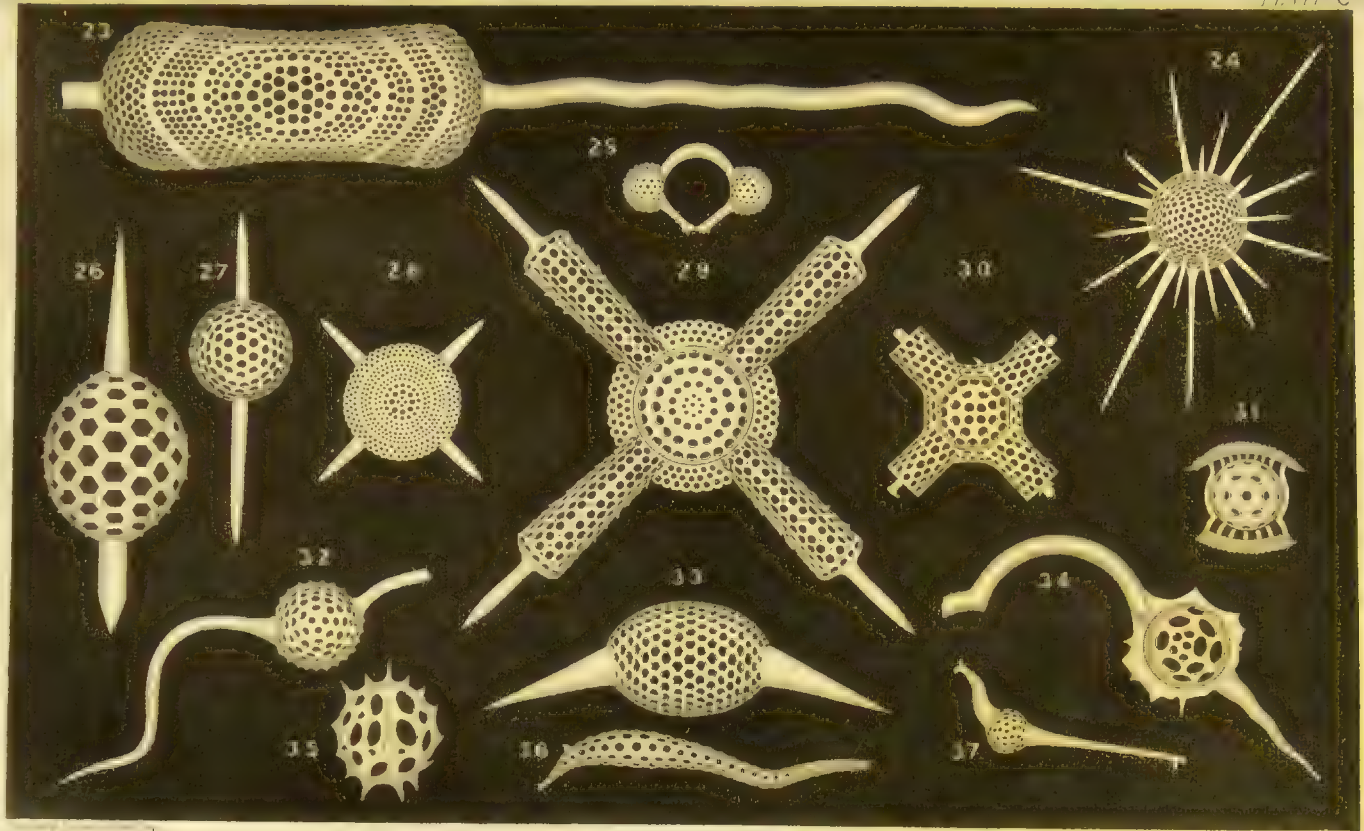
1. Eucharidium concinnum.
2. Viola cornuta.
3. Salpiglossis.
4. Monarda Whederiana.
5. Clarkia pulchella.
6. Hypericum calycinum.
7. Gladiolus Colvilii.
8. Aubretia deltoidea.
9. Erica multiflora.
10. Epilobium Halleri.
11. Echinops lamiaticus.
12. Taxanthema hinnorum.
13. Jasminium officinale.
14. Lapezia coronata.
15. Arnopogon Dalechampii.
16. Dahlia variabilis.
17. Gypsophylla prostrata.
18. Galardia anstata.
19. Tropæolum Canariense.
20. Lycesteria formosa.
21. Corydalis lutea.
22. Primella grandiflora.
23. Fuschia microphylla.
24. Zauschsneria Californica.
25. Epilobium Dodona.
26. Melittis grandiflora.
27. Weigelia rosea.
28. Prenanthes purpurea.
29. Aster cardifolius.
30. Anthyllis Italica.
31. Petunia.
32. Pyrethrum corymbosum.
33. Pinus Laricio.
34. Symphytum officinale.
35. Salvia pratensis.
36. Coreopsis.
37. Chiococco racemosa.
38. Basella rubra.
39. Epilobium angustifolium.
40. Pentstemon argutum.
41. Galium.
42. Œnothera serotina.
43. Circæa Alpina.
44. Cuphea.
45. Papaver Rhæas.
46. Godetia rosea.

PLATE A.

FORAMINIFERA



POLYCYSTINA.



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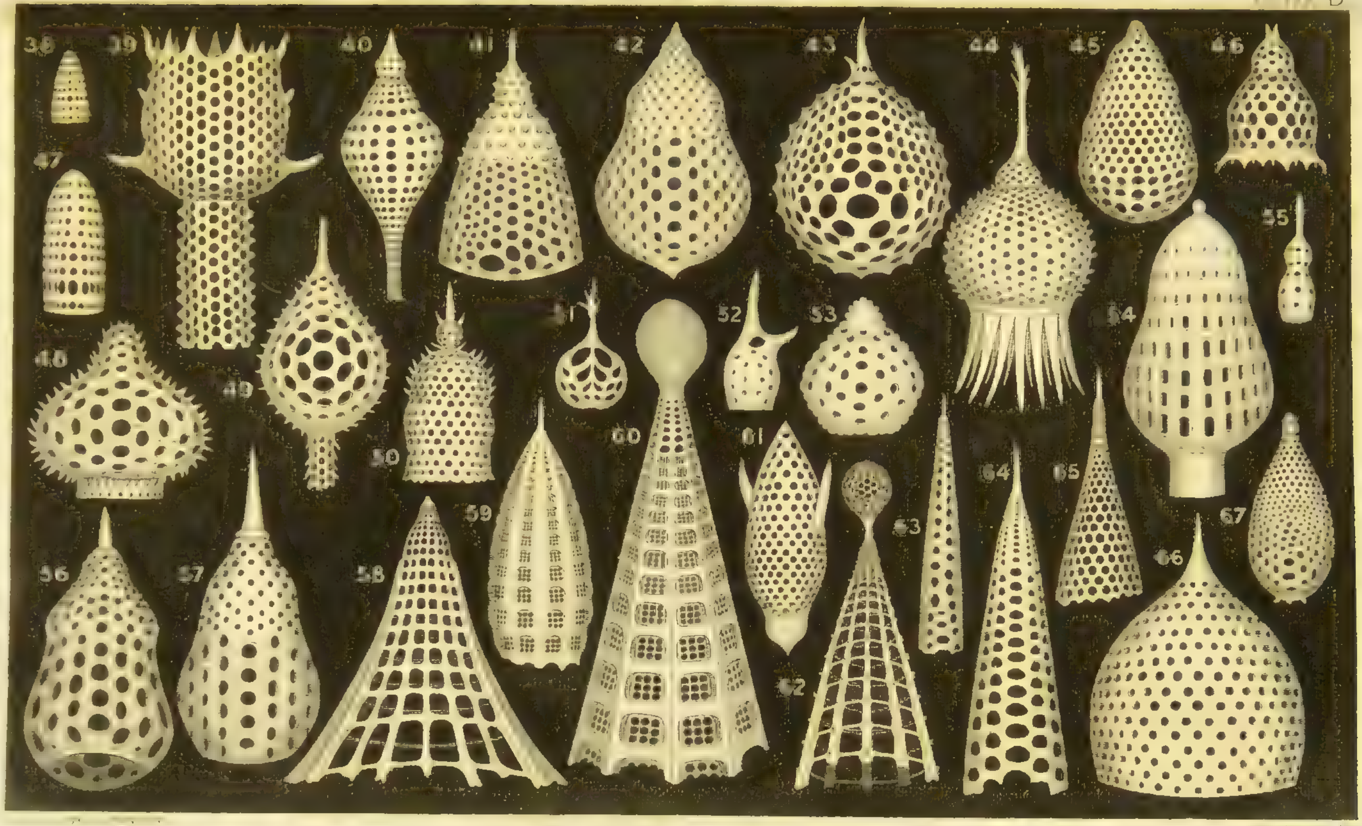

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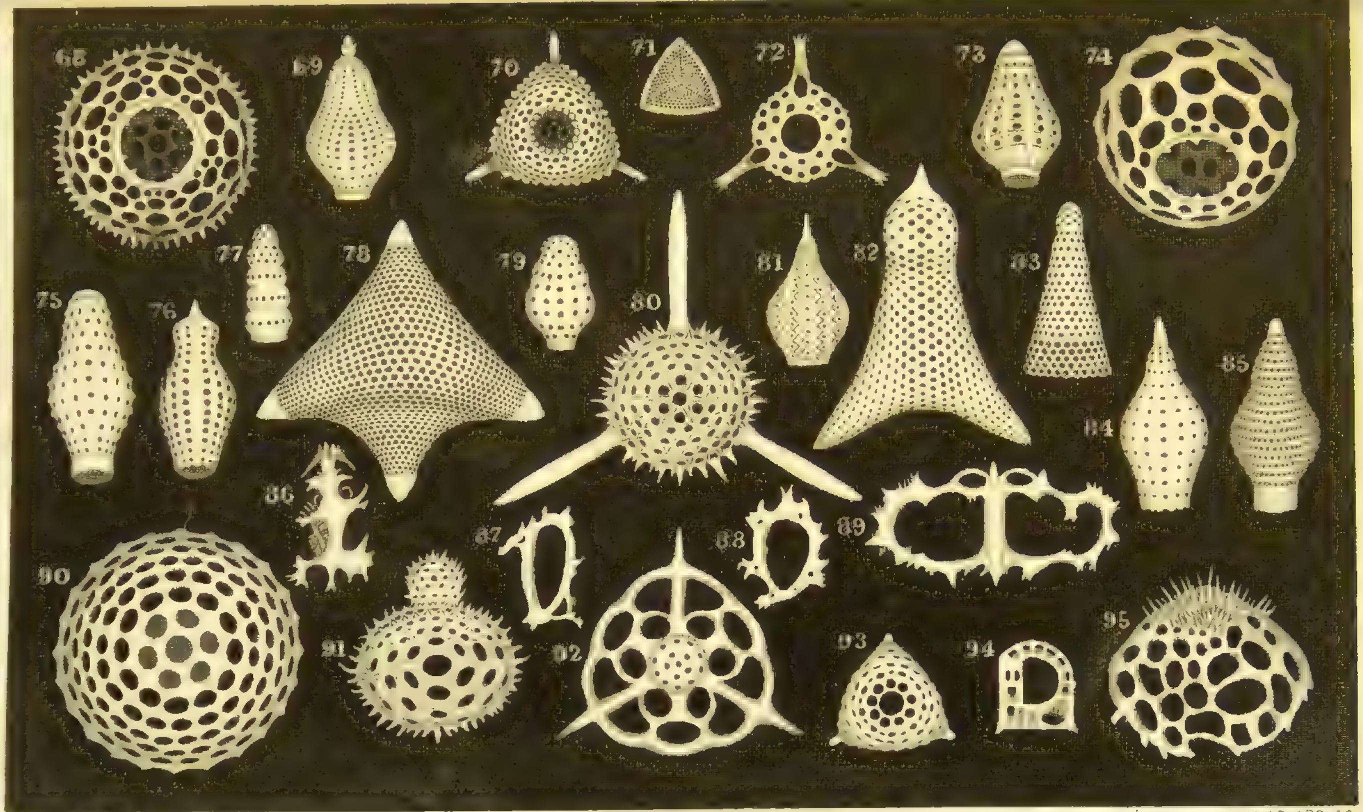
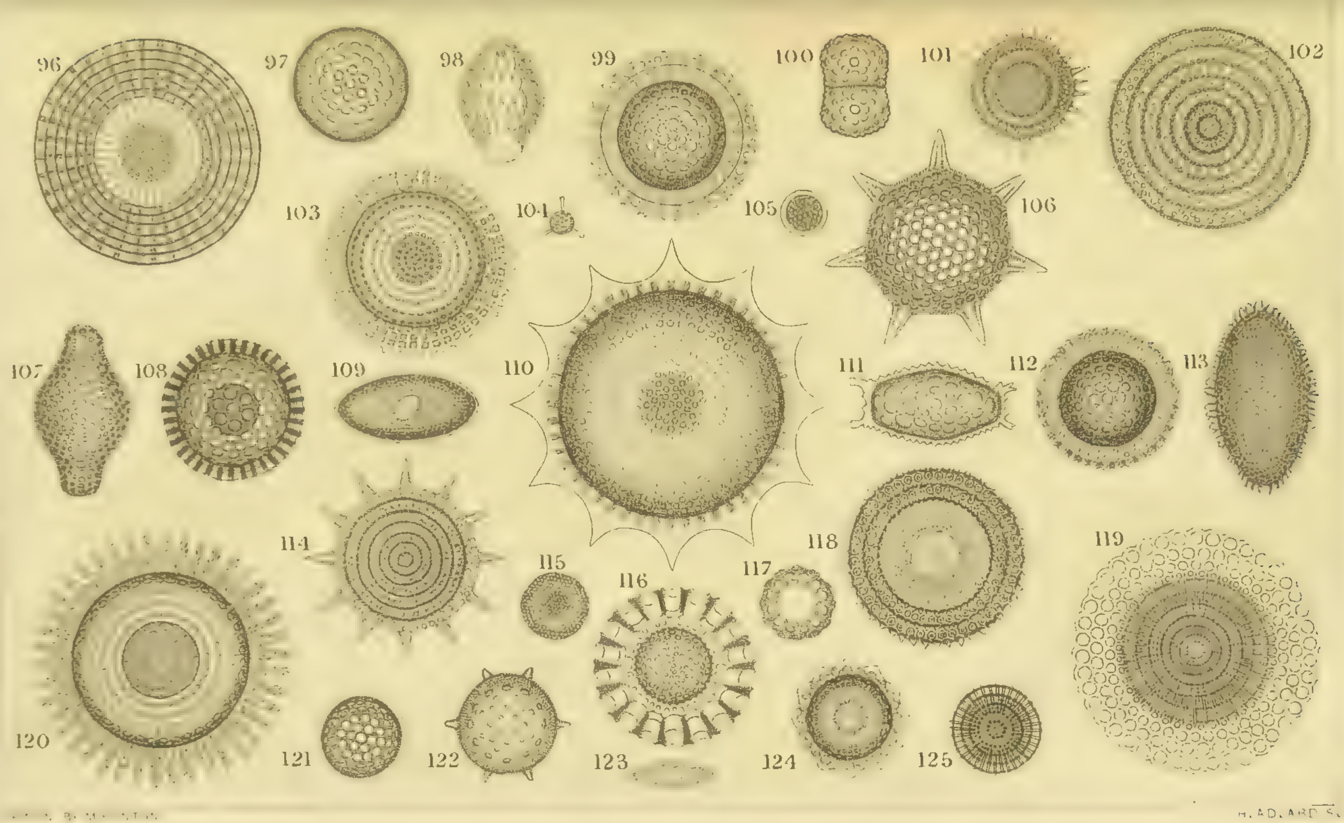


H. ADLARD SC.

POLYCYSTINA, &c.

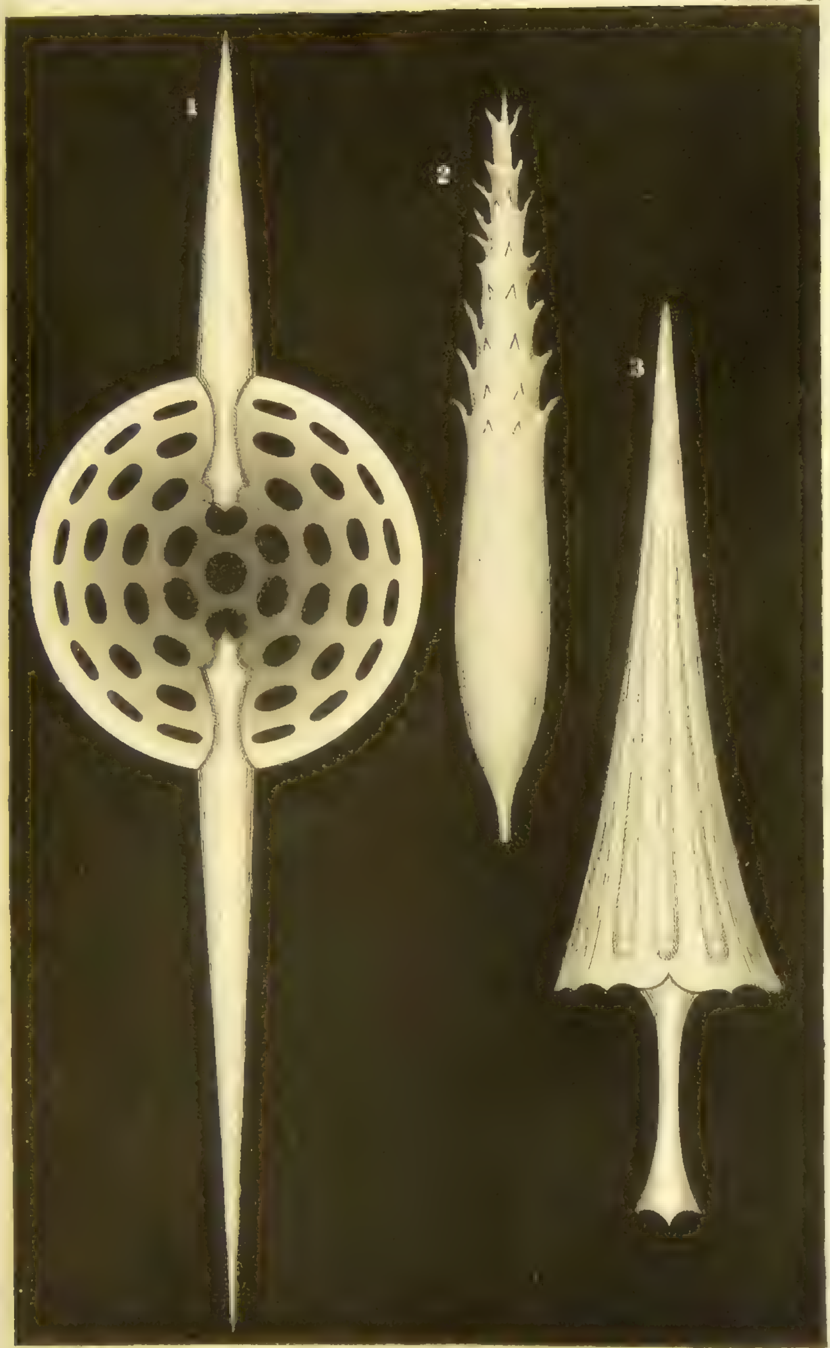
London: Longmans & Co.



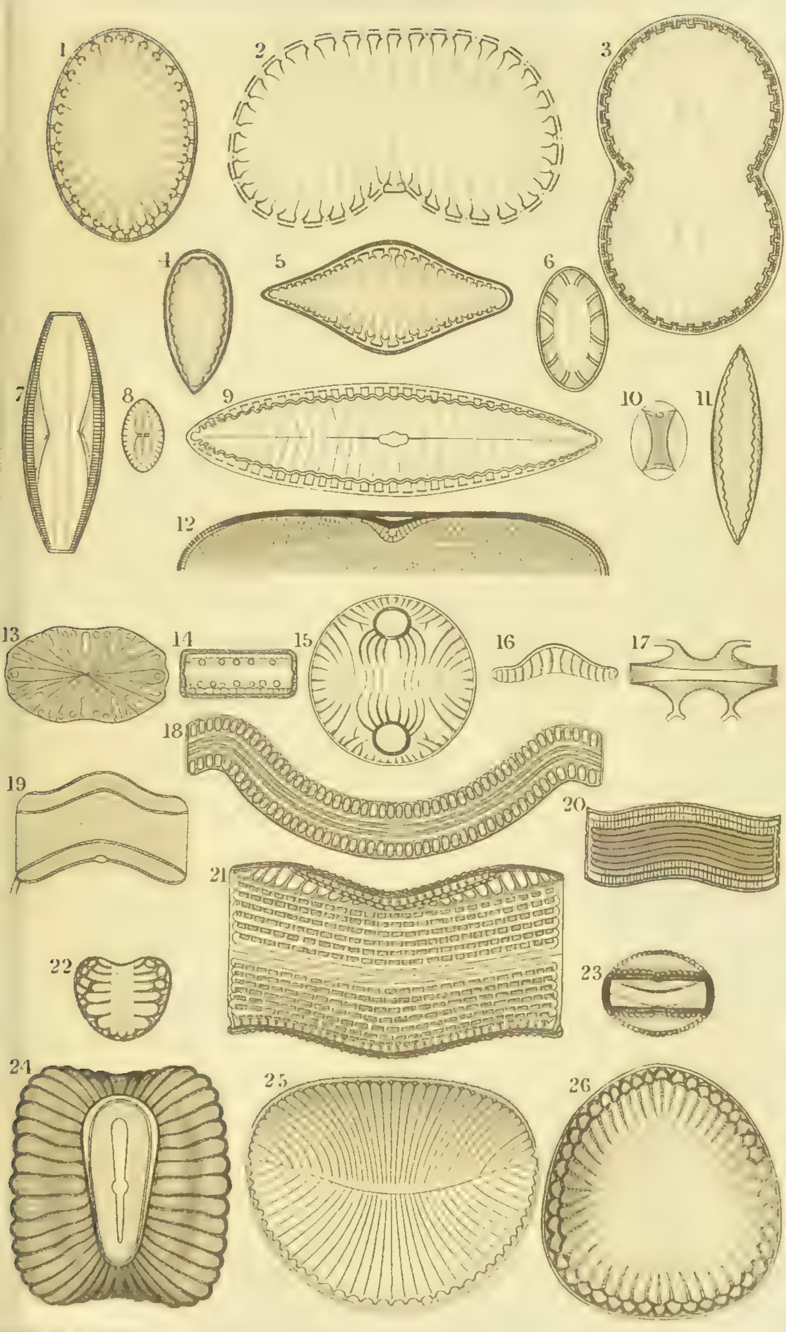
POLYCYSTINA.

London, Longmans & Co.

PLATE G.



SPIKES OF POLYCYSTINA.



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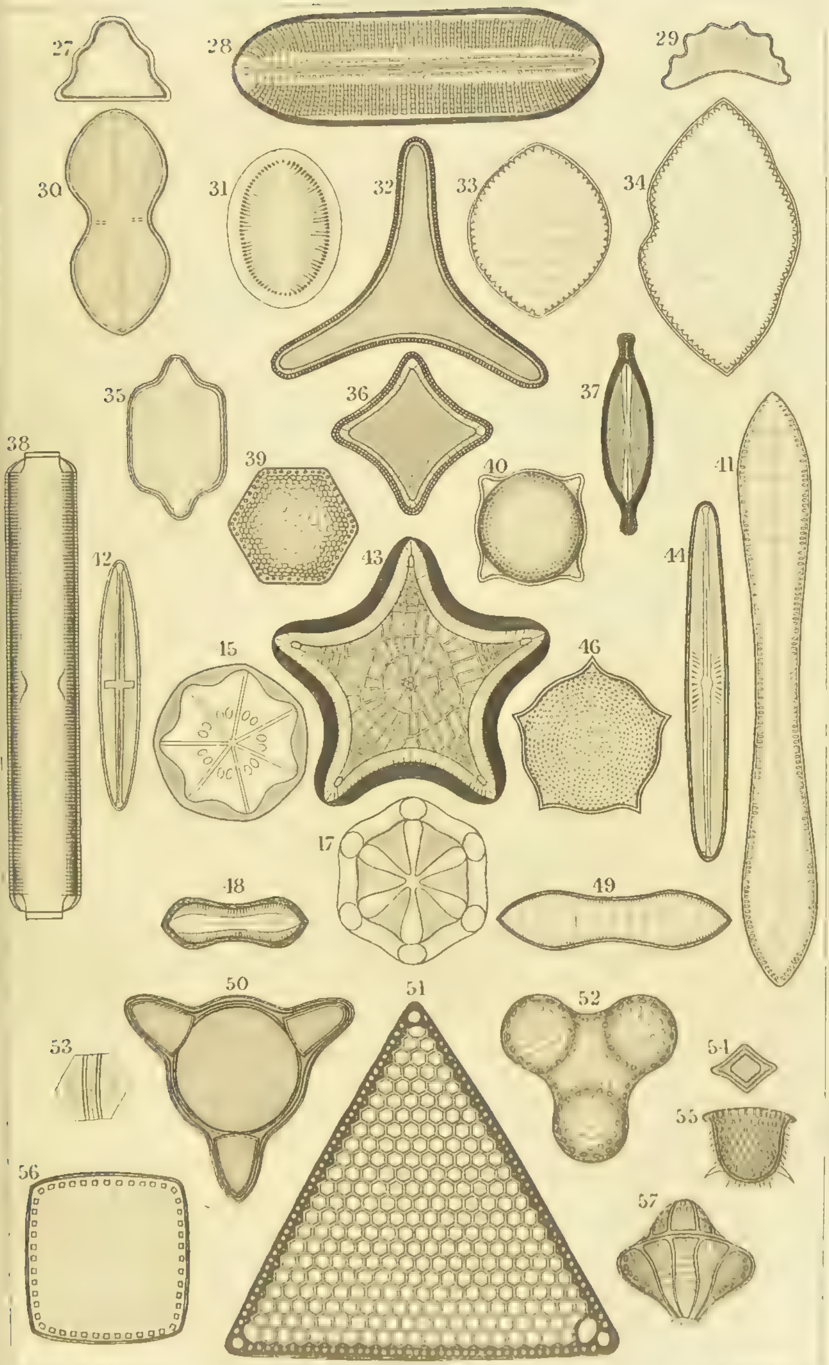
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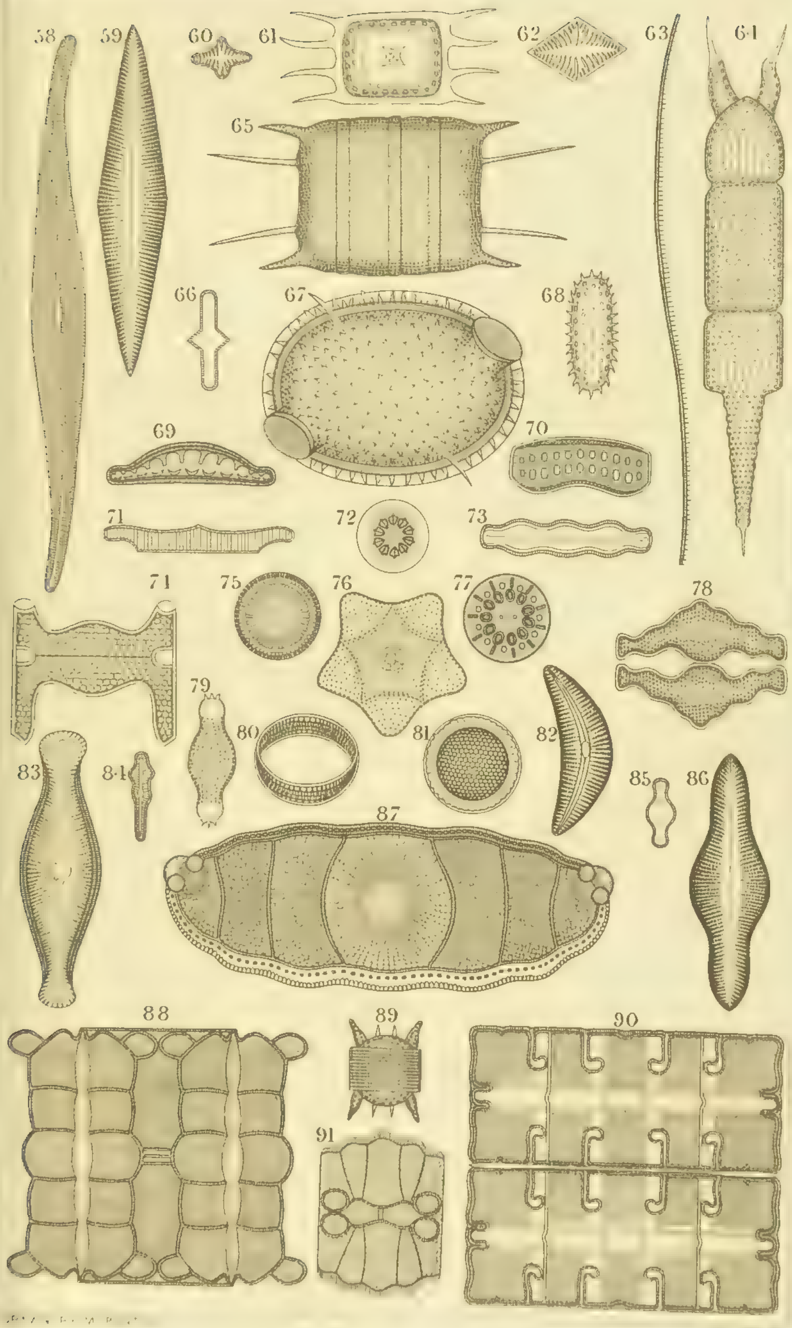
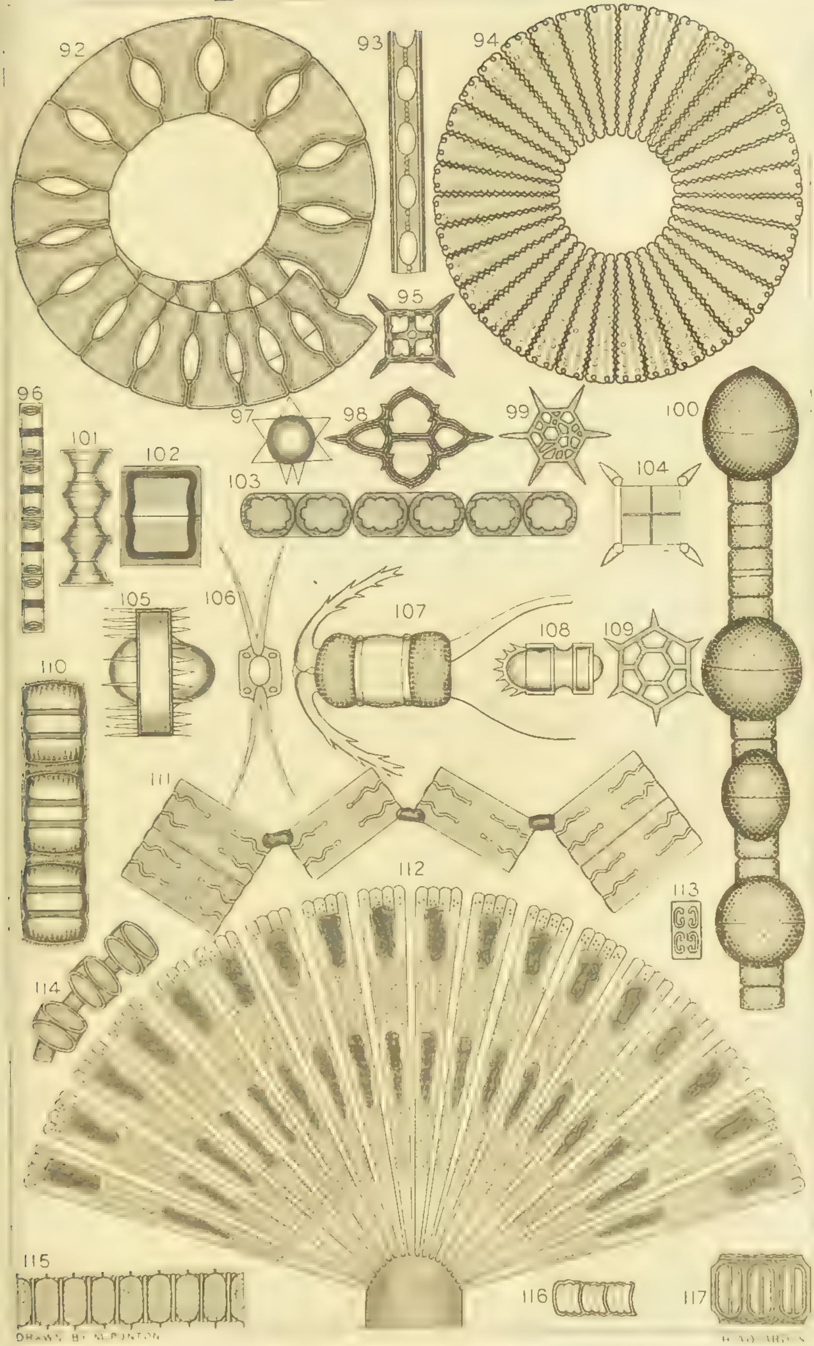
DIATOMACEÆ.



DIATOMACEÆ.

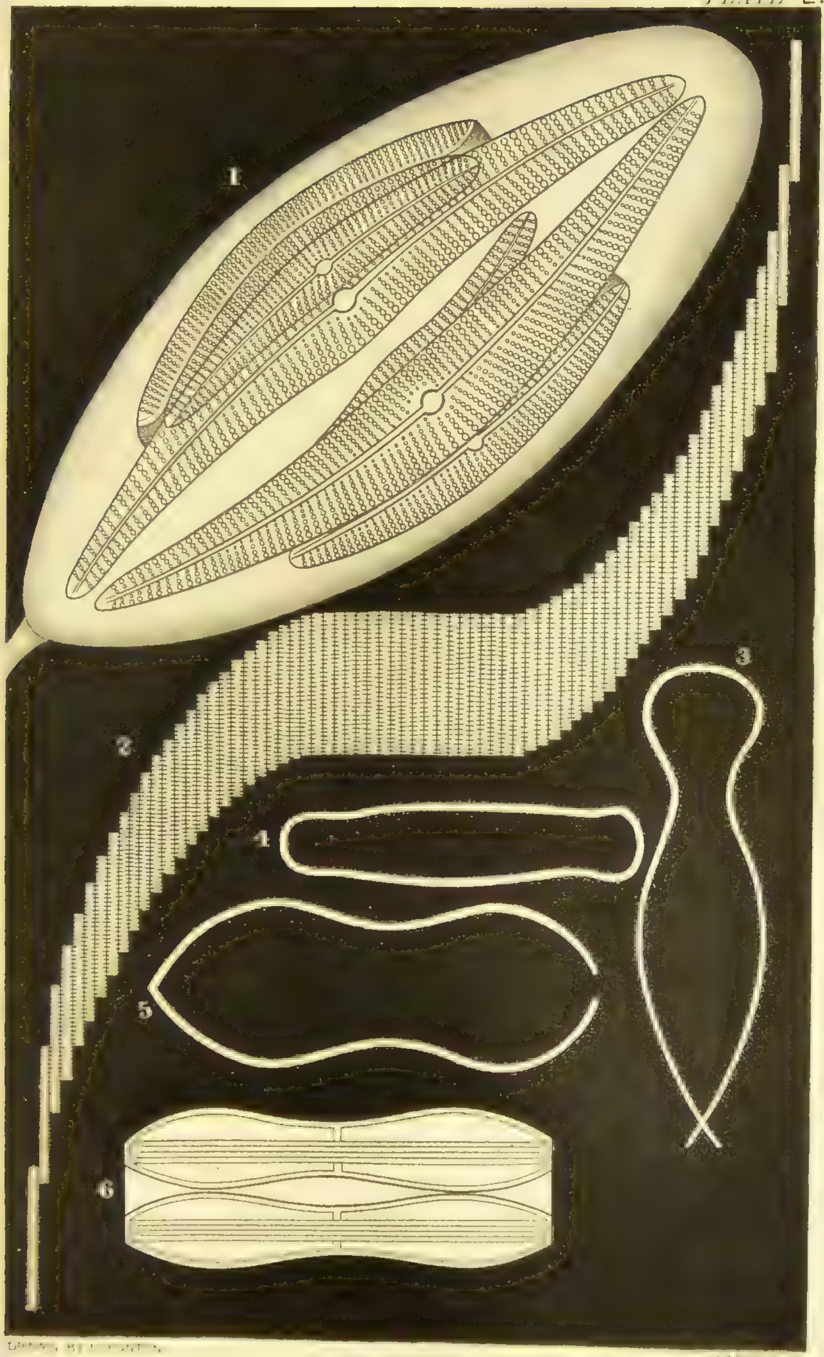
London: Longmans & Co.

PLATE V.



DIATOMACEÆ.

PLATE L.

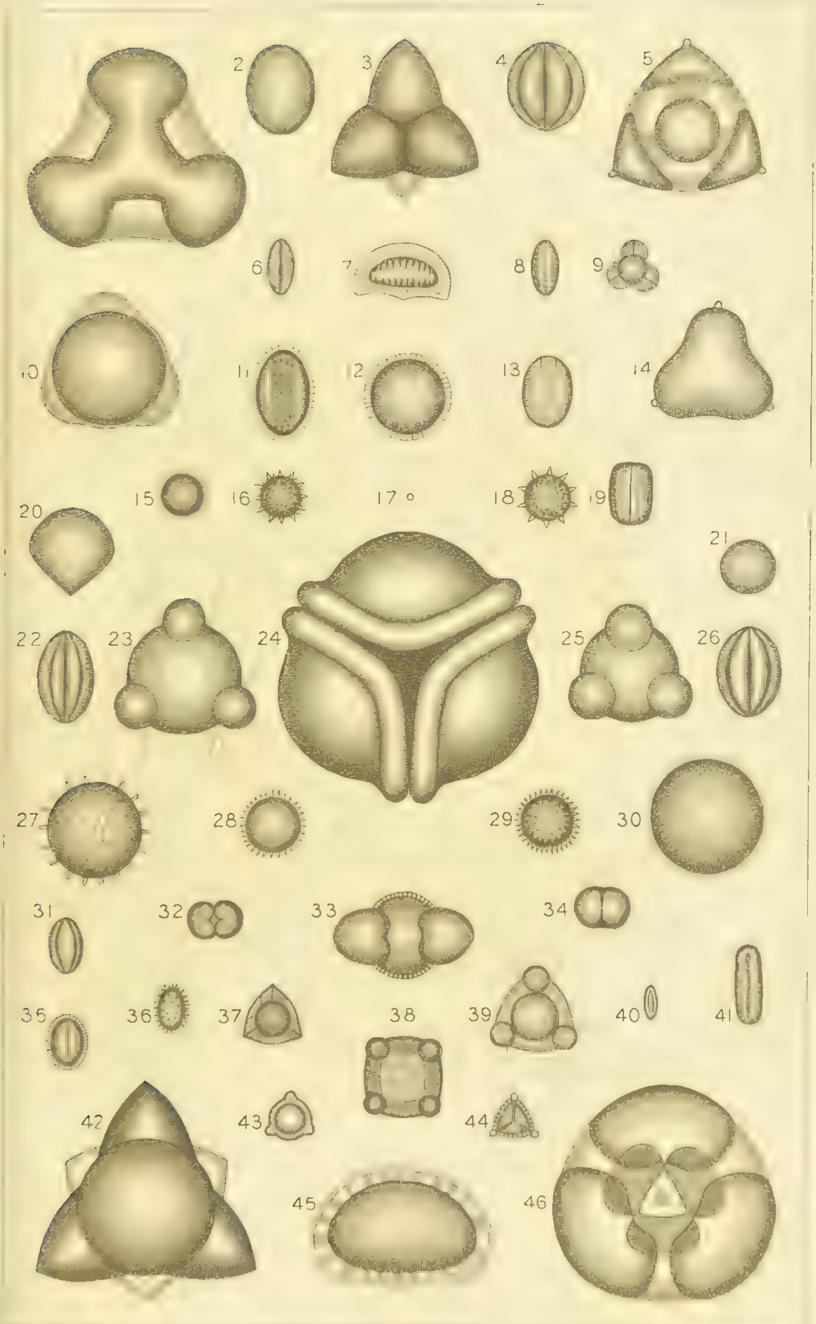


DIATOMS.

EUPLECTELLA Speciosa (half natural size)

From a Photograph by the Rev^{d} W. J. Whiting

PLATE O



POLLEN.

Fig. 1. X 75 diam.

Fig. 2. X 400 diam

1. APHIS Aceris. 2. TRICHINA Spiralis.

From a Photograph by the Rev[d] W.J Whiting

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